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SURFACE EFFECT SHIP STRUCTURAL PRODUCIBILITY. PART 1.(U)
MAY 80   N00024-77-C-2032

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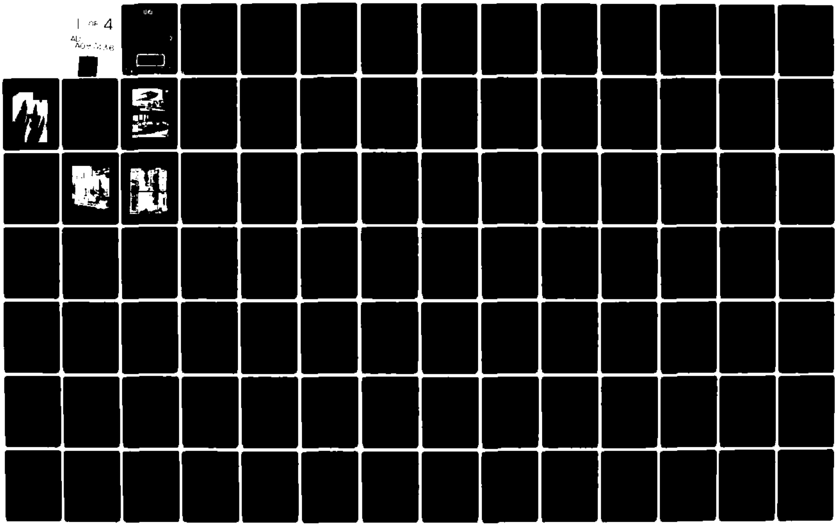

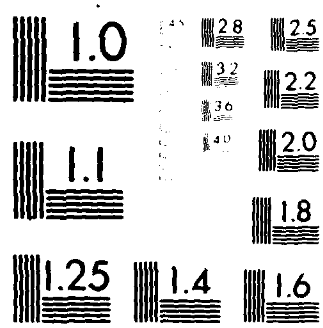

MICROCOPY RESOLUTION TEST CHART

PART 1 OF 3

LEVEL II

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SURFACE EFFECT SHIP STRUCTURAL PRODUCIBILITY.

Part I.

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1 / INTRODUCTION

For the purpose of this report the term "structural producibility" is the effect of the manufacturing process on the design (i.e., a producible design is one that is within the ability of the Manufacturing function to fabricate at a specified quality and cost level).

The producibility effort was carried out through an extensive aluminum welding, fabrication and repair technique development program; the fabrication and evaluation of the SES-100A1 bow modification and the construction and assembly of the Mini-Modules representing two small segments of the 3KSES hull. Also structural element tests incorporating various weld techniques and joint designs, including various misalignments, mismatches in the joints and various amounts of weld porosity were conducted under a separate program (Reference 1) to establish the practical limitations of the various designs and processes. The SES-100A1 modification provided valuable exposure to actual production problems, including dimensional variance due to previously locked-in stresses as well as tolerance build-up and additional induced warpage from weld shrinkage. The Mini-Module being a representative of actual 3KSES structural elements with truss joints and typical member splices exposed various assembly and weld joint crack problems which required both design and manufacturing development to resolve. → next page

In order to develop an overall optimum structural design for the 3KSES, various assembly sequences, welding techniques and joint types were investigated for accessibility, effectiveness of weld preparation and manufacturing techniques and strengths of the joints produced. The accuracy of alignment and fit-up of the various elements, having a direct effect on final assembly strength, was also evaluated to establish overall fabrication requirements.

Appendix A of this document presents the "3KSES Production Plan Appendix A Hull Structure Fabrication" Report and Appendix B presents the "Panel and Element Structural Test Program Final Report".

Appendix A specifies requirements and standards for building practices, materials, weld joint design, workmanship, inspection, acceptance/rejection, weld repair and records associated with fabrication of the Hull Structure.

Appendix B is a combination test report, test data analysis, and correlation report. It documents the testing program implemented to obtain key structural design and verification data for the 3000 Ton Surface Effect Ship (3KSES).

During the design and construction of both the SES-100A1 conversion and the Mini-Module of the 3KSES an attempt was made to record these producibility problems and their solutions, and to apply this knowledge to the design drawings being prepared for the construction of the 3KSES. The various design details which had been chosen were found to be very sensitive to the method chosen for their fabrication. For example, early designs for 3KSES tee extrusions included thin webs or flanges to be extruded in 5456 alloy. The aluminum vendors responded that it was not possible to extrude those particular shapes, It was then decided to fabricate these tees by welding up plate. This led to the need for straightening the subsequently distorted tees. If the tee had been originally designed for production as a built-up member, a better design could have resulted. The designer must take into account the materials and the method used for its production. This is part of producibility.

It was found that there were two types of producibility problems in the early design phases of the SES. The first was in attempting to use existing steel ship standard structural details for a lightweight aluminum ship. The second occurred when structure details better adapted to riveted construction were used. The best designs were those specifically intended for a MIG welded aluminum ship.

It has been found that the best welded structure has the least amount of welding. The more welding that is done, the more distortion with subsequent weld straightening required. This philosophy had to be designed into the production drawings by means of consultations between the Designer, Stress Analyst, Welding Engineer, Materials and Processes Engineer and the Manufacturing Engineer (producibility).

The overall result of the producibility program included the establishment of viable welding processes for the 3KSES production, the modification of a hull assembly method from a large module concept to a smaller modular/panel element assembly concept to improve the control of dimensional variances, reduce handling problems and improvement of joint designs and weld sequences to minimize weld cracks and distortion.

2 / RECOMMENDATIONS/OBSERVATIONS

2.1 WELDING AND FABRICATION TECHNOLOGY SUMMARY REPORT

The objectives of the effort performed under TADP (H-12) were to develop aluminum welding, fabrication and repair techniques that would support the production of the 3KSES.

The Top Level Requirements (TLR) that were particularly related to this effort included minimum ship weight, ship life of 20 years and the requirement for high speeds in relatively high sea states. These requirements generated the necessity to develop a process for fabricating a lightweight structure with high strength, high fatigue resistance and good resistance to corrosion. Accomplishment of the required ship performance objectives in either calm or rough seas placed a premium on achievement of precise hull alignment and a high degree of fairness, particularly in the sidehull structures.

The overall effect of these requirements on welding and fabrication technology was to generate a demand for welding processes which produce minimum heat affected zones, low porosity welds, good penetration, minimum undercut and other stress risers in the weld zone, and a high degree of control of material distortion introduced by the welding process.

The effort in TADP H-12 addressed the above requirements with particular attention to low cost and high repeatability of weld quality.

2.1.1 As a direct result of the H-12 Weld Development Program the following recommendations are made for use in future development of structural aluminum welding capabilities.

1. Welders without aluminum welding experience must be trained and qualified to MIL-STD-248 and repeatedly demonstrate ability to produce Class 1 welds.
2. Comprehensive training and education of welders is necessary to qualify them to meet Class 1 requirements. However, the significant reduction in weld repair costs and improved structural performance, due to the extensive training, will more than compensate for the somewhat increased cost of welder training and qualifications.
3. Aluminum welding procedures must be precisely defined because of the stringent welding parameter tolerances required for repeatable quality.
4. It is recommended that for automatic welding of butt welds and fillet welds on a panel welding machine, that a power supply with variable slope control from constant current to constant voltage be used. The panel welding machine ensures the very precise arc height and travel speed necessary to guarantee high quality welds made using a constant current power supply. It is recommended that for semi-automatic and machine welding that constant voltage gas metal arc welding equipment with a low-frequency (120 Hertz) pulsed arc be used, (the constant voltage feature because of the possible variations in the torch-to work height, and the pulsed arc to reduce total amount of heat to the work).
5. Welds of Class 1 quality were achieved in 0.125 inch and 0.250 inch square butt weld in 5456 H116 aluminum using the suspended bead method without a backup bar. Note: This was not repeatable on the SES-100A conversion or in the 3KSES Structural Panel and Element Test Program.

6. Acceptable, all position fillet weld procedures can be achieved using GMA (Gas Metallic Arc) machine and semi-automatic welding. Precise welding parameters are mandatory to ensure satisfactory weld penetration and elimination of undercutting. The general parameters for the production of aluminum welds are available in literature, manufacturers data and handbooks. These parameters include voltage and amperage settings, pulse frequency and level, wire size and feed rate, torch movement rate, skill, etc. When these "textbook" settings are applied to aluminum plates in the sizes chosen for the program, they do not always result in acceptable welds. Changes beyond those considered "fine tuning" of weld procedures are required to produce acceptable and economical welds.

2.2 SES-100A1 CONVERSION PROGRAM

The SES-100A1 Conversion Program consisted of modifying the existing 82 foot Surface Effect Ship (SES-100A) to reflect the proposed bow and stern planing seals of the 3KSES and act as a 1/3 scale model testbed, (see Figure 3-1). Figure 3-2 represents the SES-100A1 structural breakdown. Figures 3-3 and 3-4 show different assemblies at the time of shipping and under construction, respectively.

The modification gave Rohr Marine the opportunity to put into practice some of the detailed lessons learned on the H-12 Program. The results would prove the validity of these lessons and in turn would either confirm the producibility of the drawings or would encourage alternate designs which could be produced. In some cases changes were incorporated and drawings were changed to reflect this. In other cases construction continued on to meet schedules. Records and notes were kept and would be used to determine further "lessons learned".

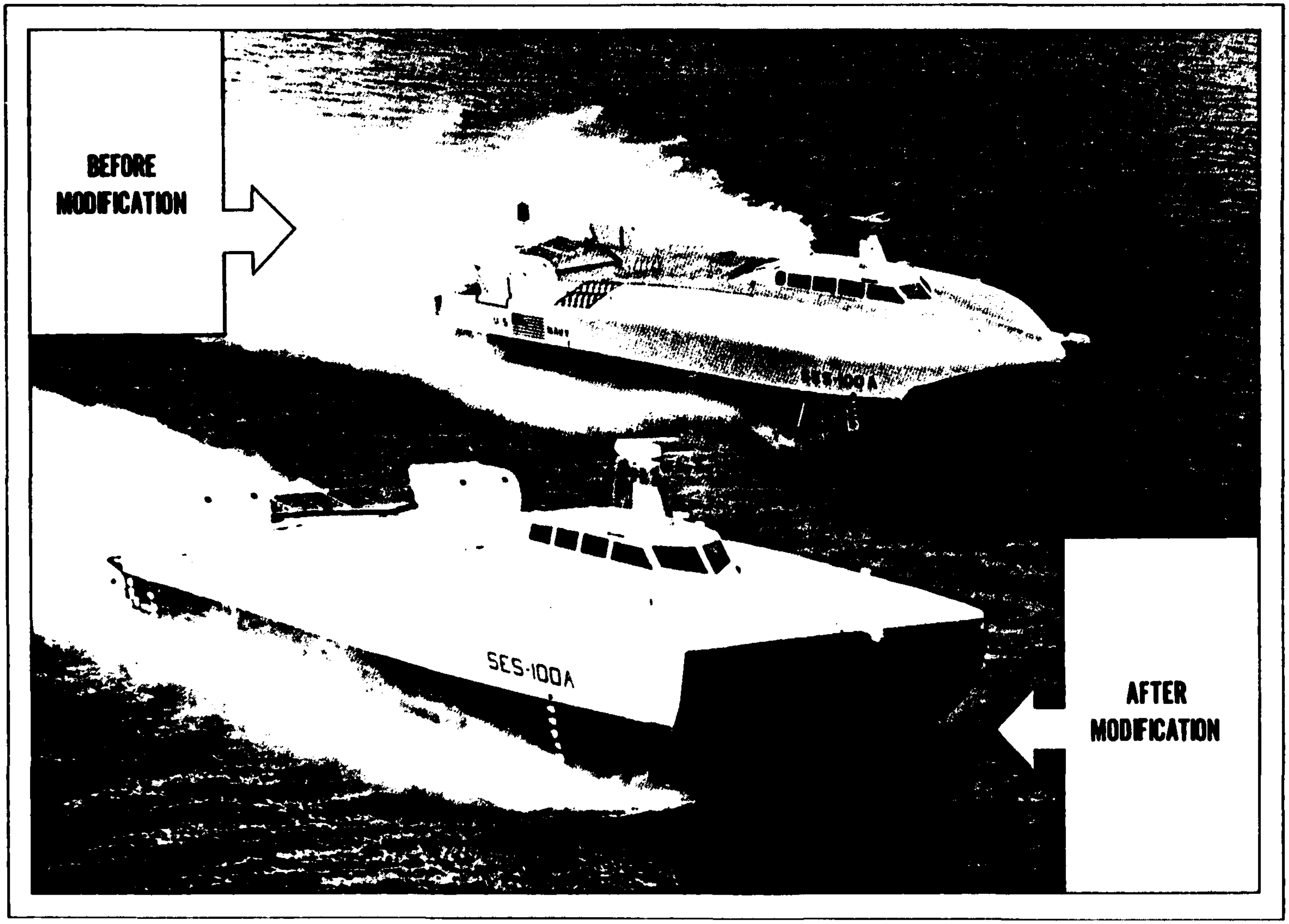


Figure 2-1. SES-100A Before and After Modification

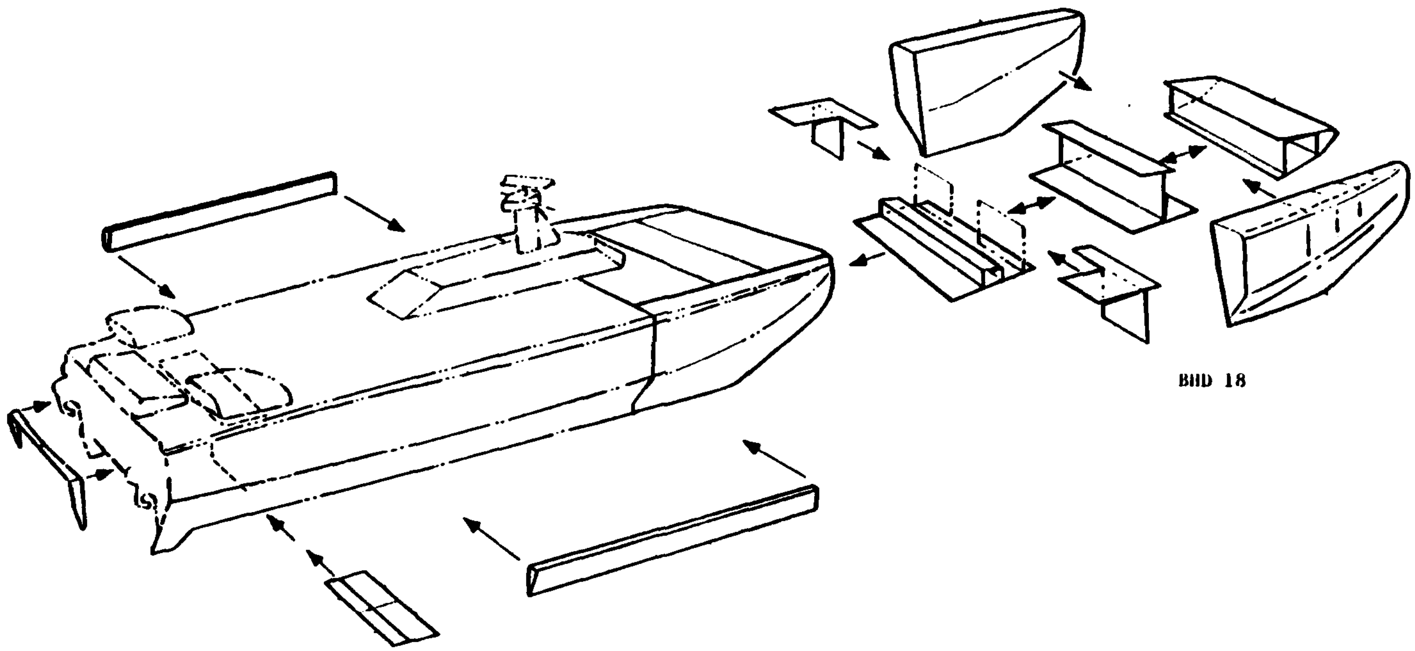


Figure 2-2. SES-100A1 Structural Breakdown

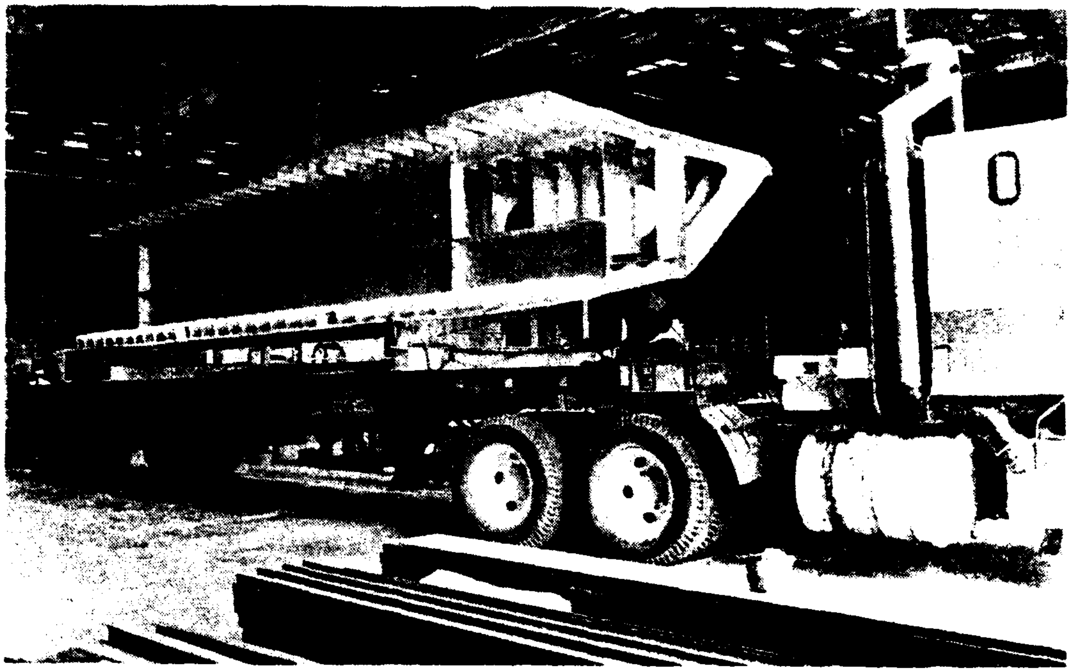


Figure 2-3. SES-100A1-01 Assembly on Shipping Crib

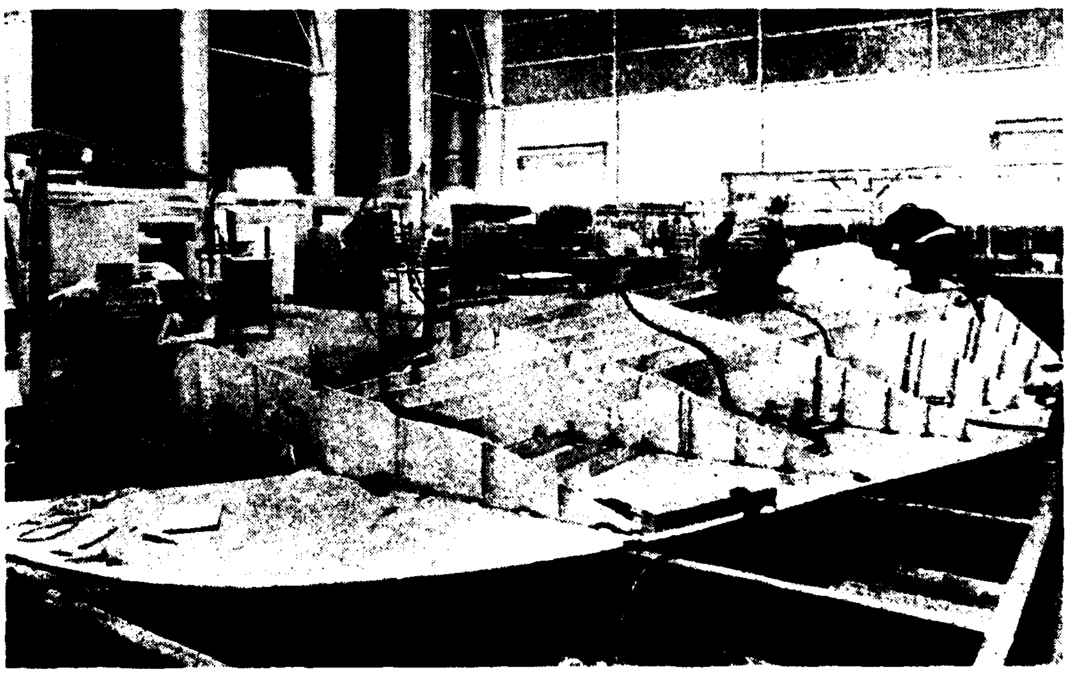


Figure 2-4. SES-100A1-06 Assembly

Some of the specific lessons learned are in the "do" or "don't" categories, however many of the lessons indicated that we needed to develop more understanding of the subject before we could identify the specific method or technique which should be used for 3KSES structural work. Examples of some of the more significant producibility lessons which were identified are:

2.2.1 The tight time schedule demands led to a mode of operation where weld procedures were demonstrated on qualification assemblies only and then released for use on production hardware. Because of the size effect, these procedures proved to be too "hot" for production fillet welds and too "cold" for butt welds, and refinement for production conditions was accomplished on the actual production welds.

Review of SES-100A1 production efforts, and consideration of the effects attributable to the above, have led to a number of conclusions on "Lessons Learned". Design development and general production planning must be in a realistic and relatively firm stage of definition with respect to significant details before attempting to identify and start development of weld procedures. Welding engineers must actively support the design and planning efforts to minimize unnecessarily difficult welding procedure requirements, and assure best possible access, position, and sequence for welding operations. Weld procedure development must have progressed to the point where a significant number of basic procedures have been developed and qualified prior to starting to train production welders. Welders used for procedure development must be trained and proficient (based upon most appropriate and available existing welding procedures) prior to participating in procedure development efforts.

Procedure development activities must be thoroughly planned and coordinated to enhance efficiency and capitalize on the "feed back" effect as procedures are developed. The definition of scope of a given weld procedure should be strictly in accordance with MIL-STD-248 taking maximum advantage of the thickness range, multiple position applicability, and the capability for

fillet weld qualification. The definition of procedure changes requiring re-qualification should be in accordance with MIL-STD-248, as a minimum. During procedure development, the full spectrum of combinations reflected in the design, which are within the procedure range, should be evaluated to establish the true range for all procedure parameters. After basic parameters have been established on typical qualification assemblies, the procedure should be further evaluated and refined on representative production assemblies prior to welding of final qualification assemblies, and submittal of the procedure for approvals. Weld procedure development should continue to pursue minimum possible number of pass welds. Structures fillet welds, and less than full penetration fillet welds. Structures Design should actively support this activity, particularly fillet procedure development, and perform tests to determine if a valid basis exists for deviation from current specifications.

2.2.2 For the SES-100A all welders were experienced, but were still required to receive brief classroom and informal "hands-on" training prior to attempting to perform a qualification test. Trainee welders were participating in weld procedure development while developing their own proficiency, and were qualified, automatically, when a procedure they worked on was qualified. The working rule was established that no welder would perform a production weld unless he was qualified to that specified procedure. Overall, this approach (which was based on our concept for 3KSES production welding) was good, and definitely contributed to the weld quality achieved on the SES-100A1.

Successes and problems encountered during the program have allowed identification of the following lessons:

1. Comprehensive training of <u>all</u> personnel involved with welding operations (regardless of extent of prior experience) will significantly improve overall weld quality.

2. The requirement that each welder must be qualified to the specific procedure to be used for production welds, prior to production welding, is essential. This did become a time and administrative problem on the SES-100A1; however, adherence to the definition of procedure (as discussed in (b) above) will markedly reduce both of these. Welders should be required to demonstrate proficiency on each weld joint to be welded, prior to performing that specific weld the first time in production; similar to "qualification" as done on SES-100A1, but without the formal administrative procedures which were invoked on SES-100A1. This approach should be accomplished during the training period. Welding operators should become familiar with and dependent upon a standard approved in-house welding procedures manual which will provide all the welding requirements of the 3KSES hull structure. The welding procedures manual should be used as a tool required to produce quality workmanship.

2.2.3 Essentially no jigs or fixtures were used for 100A1 fabrication. Platen tables and standard accessories were used to effect the equivalent of fixturing for many of the subassembly and assembly operations; and two very simple "fixtures" were fabricated, primarily to facilitate positioning the side hull assemblies for welding. Although quite rudimentary, these methods were effective; and similar, slightly more sophisticated, fixtures should be quite effective for 3KSES work when used in conjunction with with welding sequences.

A number of extremely simple production aids were created by different welders which proved to be effective. Many of these aids allowed essentially mechanization of what would have been manual welds. Savings in manhours, and improvement in weld quality and consistency were impressive.

Examples of these SES-100A1 production aids were; holders for fillet weld run-on and run-off tabs when used with the Wiggler, motorized and guided tack-weld slitters to remove tack weld prior to the actual structural welding, (as it was found that tack welds with their starts and stops were found to be a cause of weld defects such as porosity, lack of penetration and crater cracks.)

Mylar templates developed by engineering were used in lieu of hard templates by Tooling or Lofting. These templates were readily useable by Production with a minimum of problems, and were quite economical. This will also be efficient and cost effective for 3KSES. For 3KSES, Production Planning should work with Engineering in order to develop the mylar templates with appropriate trim allowances, etc.; in addition to net part molded lines.

2.2.4 Welding equipment used on the SES-100A1 conversion was selected from the best available to the industry. In general, this equipment performed well, was highly reliable, and contributed to the overall quality achieved. An automatic panel weld system was not available for 100A1, but would have been advantageous, and should be acquired for 3KSES. The automatic system proposed would focus on numerical control stiffener layout and an integral clamping system to provide for minimizing distortion and maintaining dimensional control. Planned, preventive maintenance definitely improves the performance and reliability of this equipment. Desirable modifications have been identified for every piece of equipment used for SES-100A1, and will be specified for equipment procured for 3KSES. Examples of such modifications are:

1. Digital controls and displays should be required on all power supplies, or other welding equipment control units.
2. Improved cooling systems on all welding equipment, incorporating replaceable filters or filter elements in all non-hermetically sealed cooling systems.
3. A variety of interchangeable specialty barrels for all welding torches.

4. Inert gas pre-purge and post-purge controls on wire feeders to minimize porosity and weld starts and provide continuous shielding during crater fill operations.

Cutting equipment used for SES-100A1 was marginally adequate. Cutting and other metal removal operations were manhour consumers. Improved equipment must be identified, particularly for operations such as weld bead removal for X-ray, and beveling edges of plates for dissimilar thickness butt welds.

2.2.5 Some hot formed parts were incorporated into SES-100A1 structure. There is no question that formed parts should be used, in lieu of weldments, whenever forming is possible. Designers must become more familiar with the effects of forming 5000 series alloy. Planners and Welding Engineering must work together on planning formed parts which are to be welded on, or to, after forming. In some cases, parts should be overformed to compensate for stress relieving which will occur as a result of welding. All formed parts which will be welded on, or to, after forming, should be formed with excess on <u>all</u> sides.

2.2.6 The ratio of shipfitters to welders should be adjusted to provide approximately a 1 to 2 ratio. During the 100A1 modification the ratio was 1 to 3 which created a heavy burden on the fitters who were not able to keep up with the welders.

2.2.7 The design of the SES-100A1 new structure included many details which were unnecessarily complex and difficult to weld. Most of these could have been eliminated, avoided, or significantly simplified. Examples of these type details are:

1. Weather deck, wet deck stiffener intersection of the bow (01 assembly).
2. Butt welds in sidehulls (06 and 07 assemblies) which were within one inch of a longitudinal stiffener, and the shell plating and shell vertical and horizontal butt welds which resulted in cracking in parent material where no welding had been done (along the lower chine).

3. The 1/2" insert for the mooring fittings in the 0.190" weather deck. An insert with a machined transition section from 1/2" sculptured down to welding lands of .190 would have reduced the problem.
4. Dissimilar gages in the transverse bulkheads and frames in the center bow could have been eliminated like they were at Frame 21.
5. The -10 and -11 assemblies are examples of details which could have been designed with significantly fewer welds (particularly dissimilar thickness butts), and more realistic tolerances.

2.2.8 Both GMA and GTA welding processes were employed for the SES-100A1. Use of GTAW was limited to special welds, such as keel fitting butt welds, and some repairs. GMA repair welding was done both manual and pacer assisted, and both were successful. As a result of the additional experience gained on the SES-100A1, we have observed that there are essentially two basic power supply settings for repair welds; one for manual repair, and one for pacer assisted. The key to successful GMAW repair in either case is not in the machine settings, but in assuring defect removal (even if the grind out results in complete removal of the original weld in the local backing under the repair area, locally applied heat (using heat lamps) to avoid thermal shock, use of run-off and run-on tabs to prevent arc strike or termination on the production part, and (most important of all) to require the welder to simulate the actual repair in order to develop his understanding of the required torch handling technique to effect a successful repair. GTAW was found to be a very effective process for welding very thick sections, limited access areas, very short butt welds fillet weld wraparounds, and butt weld repairs using DCSP.

2.2.9 Allowances for trim length on stiffened panels should be provided on two edges only. Base line layout techniques have shown that dimensional control can be maintained by referencing all layouts from neat edges in the x and y directions. Excess material should not exceed 3 inches.

2.2.10 Consider the alternative of drop-in sections of bulkhead plating as well as drop-in stiffeners.

2.2.11 Joints requiring two members to intersect at 90° (Figure 2-5) with a butt connection causes a high strain concentration at its ends and produces shrinkage cracks. A more comparable intersection is also shown in Figure 2-6.

2.2.12 Don't have a stiffener or a chock as wide as the flange it intersects. It should be narrower to leave room for a wrap-around weld.

2.2.13 Don't add gusset plates where it can be made as an integral part of the member (Figure 2-6).

In addition to a lesser number of less difficult welds, if there is a great disparity in the thicknesses of t_1 to t_2, the knee member (t_3) shown in "A" can be chosen to act as a transition member. If a gusset is used as in "B" the problem of cracking exhibited at pt"a" is transferred to points "b" and "c".

2.2.14 Don't handle prepared edges which are to be welded. Even cotton gloves have caused porosity.

2.2.15 Tack welds incorporated into structural welds have been one of the leading causes of linear porosity in butt welds.

2.2.16 Shrink welds must be treated as an inspectable butt weld.

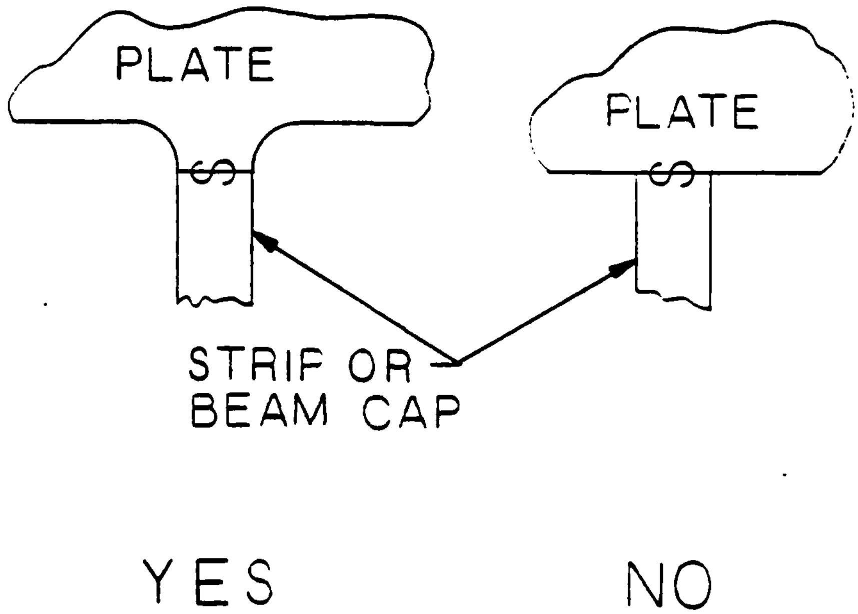


Figure 2-5. Ninety Degree Butt Joint with High Strain Concentration

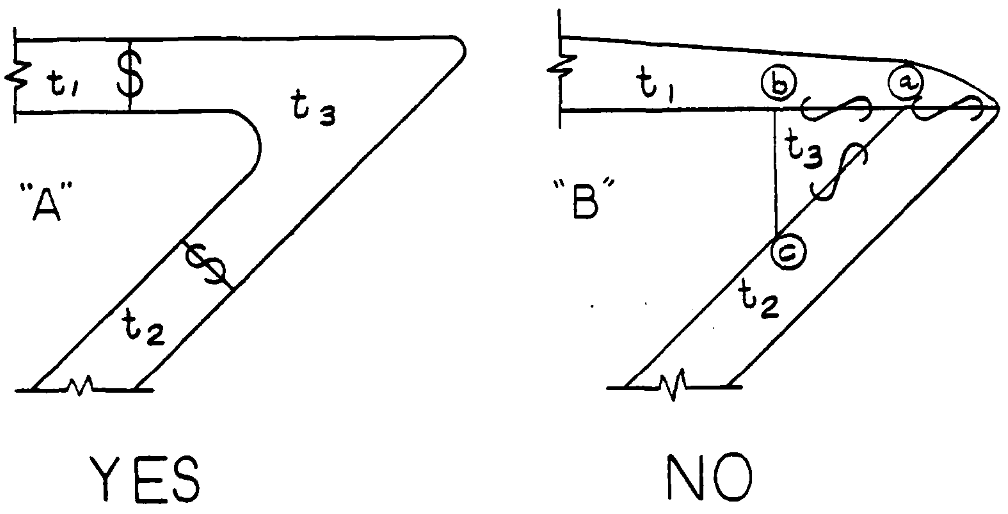


Figure 2-6. Typical Longitudinal Bow Framing

2.2.17 Don't make a shrink pass in an area which will be under a fillet weld.

2.2.18 Don't try to fuse a crater crack at a weld stop. It must be chipped out completely.

2.2.19 Copper inclusions must not be left in weld. It forms intermetallic compounds with aluminum which are extremely brittle. These brittle compounds extend a considerable distance away from the residual copper particles.

2.2.20 Welding of large sections of shell plating to periphery, before welding to intermediate frames and stiffeners, must not be permitted. This "drum-heading" leads to over-tightening of the shell plating and possible buckling of the peripheral members. This occurred in the welding of the furthest forward section of the wet deck.

2.2.21 Consider the application of the shell plating to stringers before the stringers and plating are welded to the frames. Do not weld the stringer to the frames first as this leads to buckling of the stringers.

2.2.22 Don't attempt the impossible type weld joints like full penetration fillet weld from one side against no backing or back-up.

2.2.23 Investigate the possibility of porosity caused by using anodized aluminum for back-up bars. Several used pieces show evidence of arc damage. This means surface pick-up by the weld bead drop-through. It's known that the anodized layer is hydrated aluminum oxide which is a prime cause of porosity in aluminum welds.

2.2.24 Anodized or alodined aluminum scrap should not be welded to permanent structure. The oxide layer transfers to the weld bead together with its water of hydration.

Scrap aluminum of unknown alloy content should not be welded to a permanent structure; this can introduce deleterious substances into the parent material which can lead to cracks. Check finish and alloy content of strongbacks and lifting and handling lugs before welding to permanent structure.

2.2.25 Don't try to inspect a weld joint by x-ray through several thicknesses of metal without holding the film directly against the weld being inspected (Figure 2-7).

2.2.26 The final step in the clean-before-welding process must be to solvent wipe, to remove any oil or dirt, and then to stainless steel wire brush immediately prior to welding, to remove oxides which produce porosity.

2.2.27 Don't design or analyze structure assuming that it will be built perfectly. Allow for a predetermined level of warpage.

2.3 3KSES MINI-MODULE PROGRAM

2.3.1 BACKGROUND -- The Mini-Module consisted of a 24-foot section that straddles a major ship erection splice and contained two longitudinal bulkheads fourteen feet apart and three decks (13 feet total height). There were four transverse frames forward of the erection splice and three transverse frames aft. (Figures 2-8 and 2-9)

The Mini-Module Program objective was to verify the integrated system which Rohr Marine, Inc. proposed to adapt for production of the 3KSES. Lessons learned during the TADP, SES-100A1 conversion and Structural Panel and Element Test Plans were to be applied during the design, planning, production and inspection phases. Any changes to the design would, wherever possible, be incorporated using the same methods that would be used during full scale production of a 3KSES. Where the possibility of alternate designs, weld sequences, fabrication methods, etc. existed, every effort was made to incorporate all viable methods in order to evaluate relative producibility advantages. Evaluations were made of these alternates and their costs in time, manpower, quality of welds, etc .

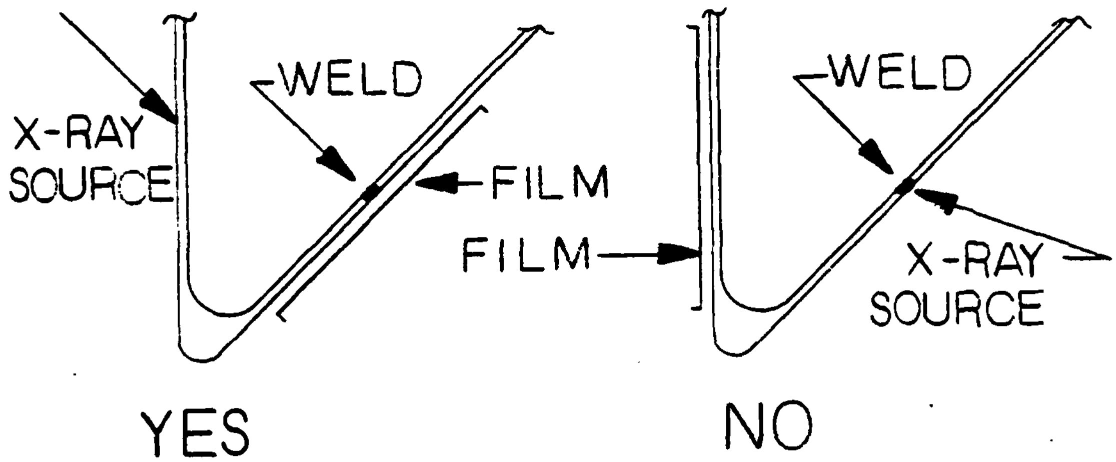


Figure 2-7. Proper Radiographic Film Location

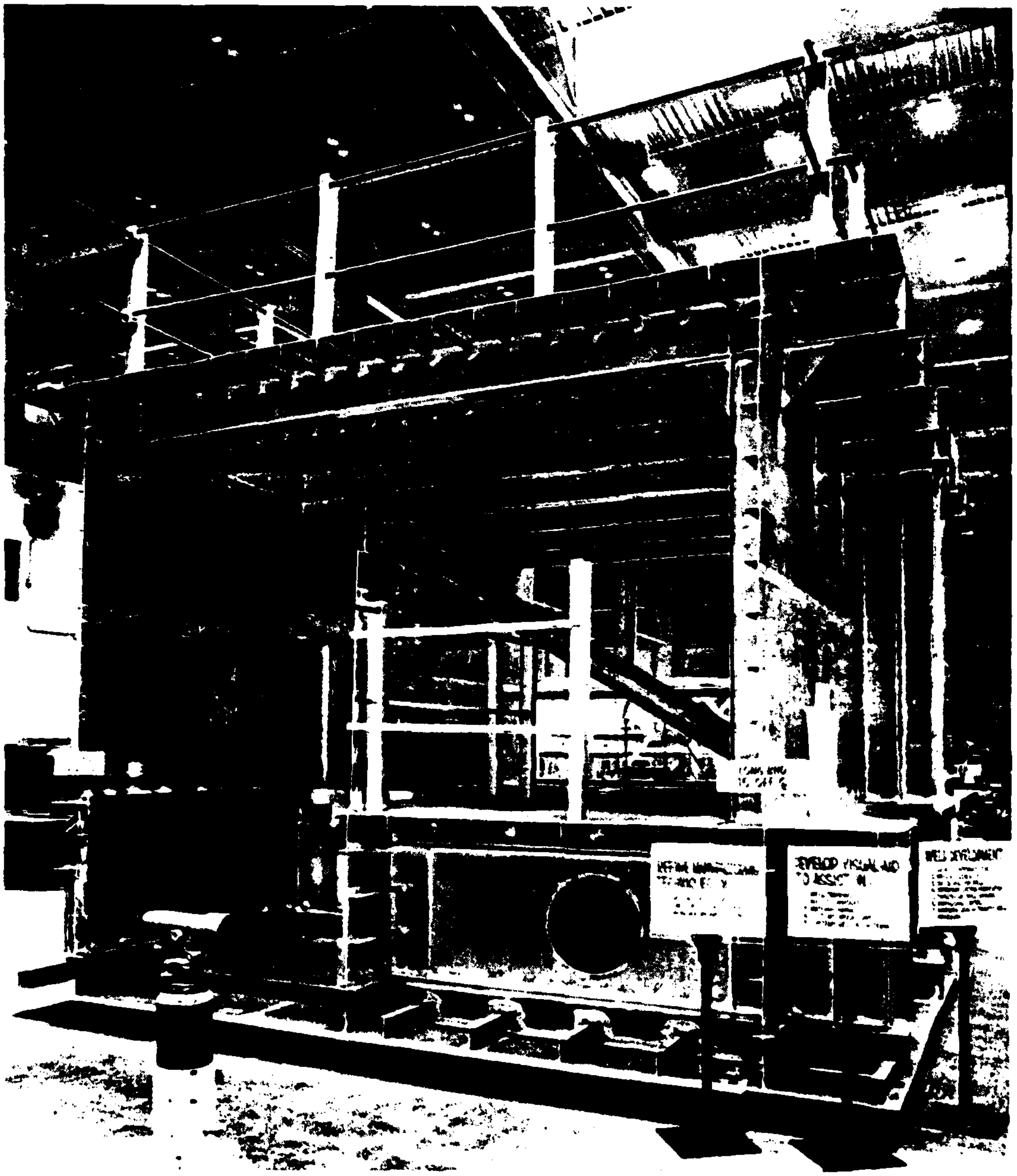


Figure 2-8. Looking Aft at Mini-Module longitudinal Bulkhead Showing Second, Third, and Wet Decks

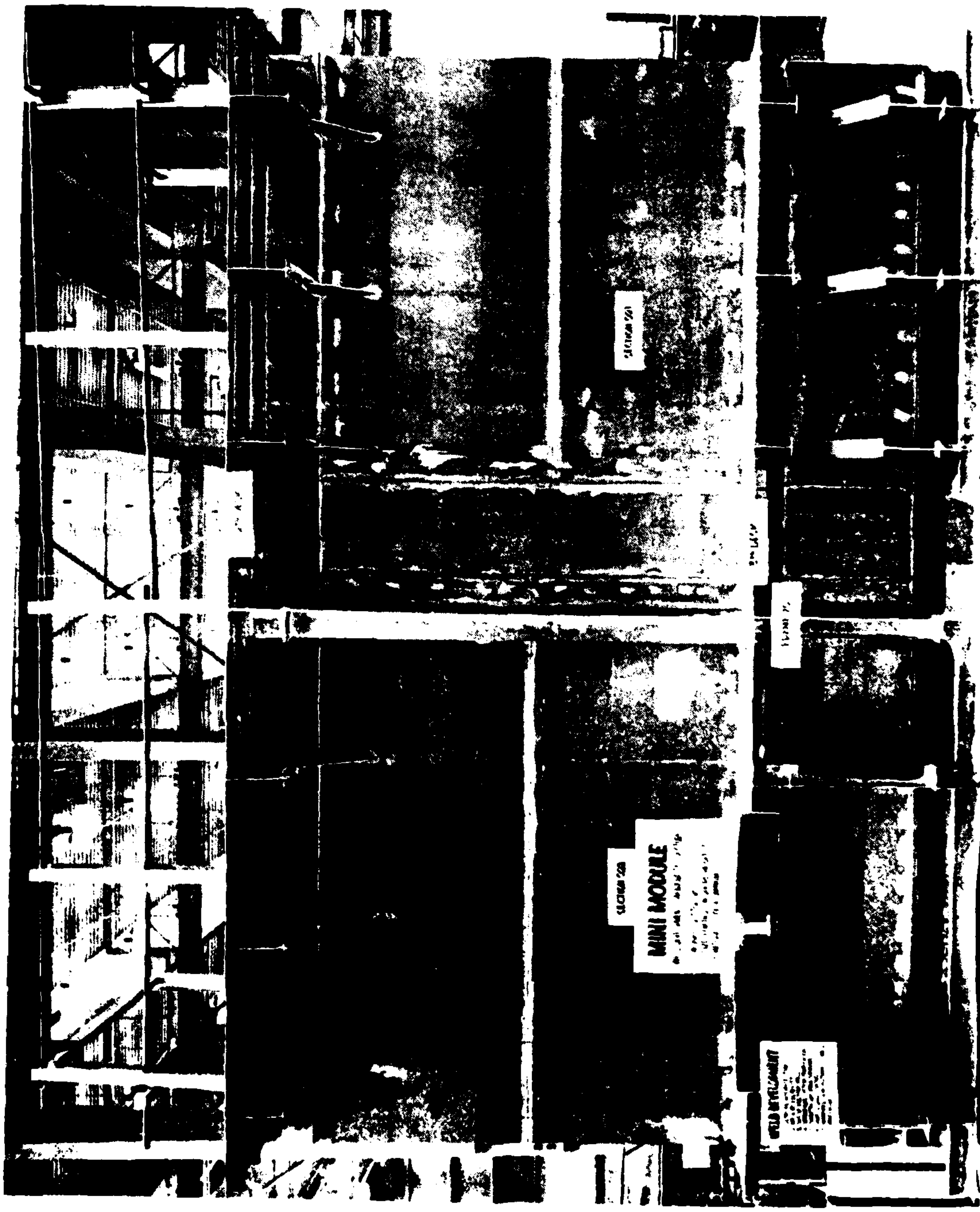


Figure 2-9. Looking Outboard at Mini-Module Longitudinal Bulkhead

To fabricate the Mini-Module, a team of personnel from Hull Structures (Engineering), Manufacturing Engineering, Welding Engineering (Production), Material Control, Production, Quality Assurance, Industrial Engineering and Operations Management was formed with the express purpose of designing, planning, fabricating and inspecting a representative section of the complex aluminum structure of the 3KSES.

These experiences have provided RMI personnel with solutions to problems not previously identified or encountered in prior construction efforts as well as verifying those procedures thought necessary for 3KSES construction.

2.3.2 SCOPE -- The evaluations that were to be accomplished included assessments of:

1. Welding parameters, to derive the minimum number of sets of procedures necessary to perform the required welding operations. Included in this area is the development of data and methods to predict reasonable parameters for non-standard gages.
2. Welding techniques and sequences to be employed to produce each representative type of weld required for the ship, as a function of location in the ship and the physical and visual access afforded.
3. Shrinkage factors, fit-up tolerances, and welding techniques and sequences which minimize distortion, dimensional deviation, and frequency of quality defects in finished weldments.
4. Welding equipment, devices, fixtures, and production aids which maximize the potential for automation or "effectively" automating of welding operations, and which lend themselves to minimizing distortion, dimensional deviation, and frequency of quality defects in finished weldments.
5. Methods and techniques for tack welding which minimize subsequent metal removal operations, and distortion, dimensional deviation, and frequency of quality defects in finished weldments.

6. Methods and techniques for removal of defects in welds, and for repair welding after such removal, which provide maximum potential for producing acceptable quality welds with only one repair attempt. Included in this area is evaluation of the effect of multiple removal and reweld attempts.
7. Methods and techniques for cost effective distortion removal to be employed when pre-weld fit-up tolerances are exceeded or post-weld fairness criteria are exceeded.
8. Methods and techniques for cost effective metal removal when required as part of weld preparation, repair of rework, preparation for necessary quality inspections, or to meet hydrodynamic or other fairness requirements.
9. Ability to incorporate new techniques and methods which were not planned in the original concept of the Mini-Module.
10. Tested the response time of the production support teams (engineering liaison, planning, manufacturing engineering, welding engineering) to typical "shop goofs".
11. Tested and evaluated the effects of aluminum welding in an outdoor environment, close to a large body of sea water under condition of wind, fog and bright sunlight.

2.3.3 STRUCTURAL DRAWINGS -- The drawings issued were completed in very limited time and had to include all the fabrication alternates for the different options of the Mini-Module. The Production Plan for the 3KSES changed and the new fabrication concepts had to be folded into the design of the Mini-Module. This required drawing changes which were generated by the use of Engineering Change Requests (ECR's) and Engineering Orders (EO's). A full-time engineer was located on the shop floor to support a liaison effort. Shop drawings were "red-lined" to reflect the required changes. It was not always possible to include these changes into the planning documents which actually authorized creation of the hardware. Hence it was decided that wherever an anomaly occurred which could not be readily reconciled, the "red-lined" engineering drawing should be the final authority for the production.

2.3.4 TEE's (Figure 4.3) -- Certain structural details such as "Tee to Tee" intersections at right angles proved to be difficult to weld with consistent high quality. Consultation with other shipbuilding companies building high-speed aluminum ships indicated that they had encountered similar problems and were only able to make these welds with extensive hand rework. The welding procedures which were developed on the bench successfully proved to be quite difficult to weld on panel assemblies. Manufacturing spent a great deal of time trying to arrive at producible solutions within economic constraints. Stress analysis indicated that many of these connections were capable of being modified by sniping the flange of the discontinuous "Tee" and using a gusset plate to give the bending stiffness that would be provided by the flange connections. Where structural transverse bulkheads interfaced on the transverse "Tee" frame, the gusset could be dispensed with. Where neither of these were possible (in very few connections) a weld technique involving GTAW and GMAW with fully attached starting and stopping tabs was used to produce welds of acceptable quality.

2.3.5 FABRICATED TEE'S -- Extrusions were not available for the Mini-Module fabrication effort. Consequently, Production was required to fabricate the necessary tees by cutting plates and fillet welding them together. At least ten (10) distinct weld sequences were used in an effort to minimize distortion caused by welding. No matter what weld sequence was employed, significant bowing distortion resulted. Disappointing distortion measurements were recorded for each of the "Tee's" produced and resulted in a decision to stretch straighten the "Tee's" using the Rohr Industries' Hufford hydraulic stretch press. The "Tee's" were individually stretched with an average elongation of 1/2 to 2-1/2%. This proved to be very successful and straightness was recorded well within the standard extrusion tolerances. A cost trade-off study was done to compare buying extrusions to fabricating the same. Buying extrusions proved to be the most cost-effective. Only two (2) sizes of "Tee's" designed for 3KSES cannot be purchased and will have to be manufactured. It is anticipated that stretch straightening will be employed to remove distortion from those welded "Tee's".

2.3.6 MOUSEHOLES -- Occasionally, during assembly and erection, intersections, butt joints and fillet joints occurred which caused concern about weld defects at the junction. Mouseholes were designed to alleviate the problem of welding one joint which crosses an unwelded joint producing an inherent unacceptable weld defect in the way of a butt weld. Mouseholes are very difficult to cut when details are assembled and only irregular cuts can be made at best, necessitating a requirement to design and pre-cut mouseholes in members prior to their assembly. Mouseholes were designed to be at least one (1) inch in radius which provides for both welder accessibility as well as good separation of the butt joint from the fillet joint.

2.3.7 INSERTS -- Wherever welded inserts were used, particularly during erection operations, butt welds were made prior to fillet welding operations. In many cases, mouseholes would have reduced the strength requirements of the stiffener and had to be eliminated. Fatigue studies from manufactured details representing this condition showed that cracking initiated at the intersection of the fillet weld where it crosses the butt weld. To correct this condition engineering determined that an "oil-stop" prep be made at the intersection prior to welding operations providing for full penetration fillet welds in the area where the butt weld and fillet weld intersect.

2.3.8 WELDING ACCESSIBILITY -- Accessibility of weld joints was the subject of a continuing investigation in the review of the 3KSES drawings, particularly in the areas of coamings. Several cutouts were made on the Mini-Module, and coamings were attached during erection; this provided production with special welding problems during weld-out operations. Two coamings were located three and a half (3-1/2) inches from bulkheads which proved to be very difficult to weld because of access difficulty. The first coaming welded was done twice as the first attempt was unacceptable. The second attempt was far better than the first, however, it was not of the same quality normally accomplished. Specific considerations for welding accessibility are: operator visibility, operator physical limitations, and weld equipment limitations. It should be noted that welding equipment

limitations vary from one welding process to another requiring that considerations must be made for accessibility based on a specific welding process and related equipment which in turn affects the operator's specific physical limitations.

2.3.9 WELDED ERECTION SPLICING INSERTS -- During the erection operations of the Mini-Modules several approaches were tried to fit and weld decks, longitudinal bulkhead inserts, and deck/bulkhead stiffener inserts. The deck splices were welded from both sides with consistent success. The fitting of deck butt joints was accomplished by trimming the excess off one edge to match the net edge of the opposite plate. This method proved to be successful with very few problems. Longitudinal bulkhead inserts were fabricated using two different methods. One method called for cutting out a curved portion of the bulkhead on the top and bottom while overlapping the middle portion between decks. The other method called for cutting each bulkhead interface short leaving a rectangular opening between the decks. The latter method provide not only to be simpler to fabricate, but required only half the time to complete fitting and welding operations. Another advantage of the latter method was that it also provided "walk-thru" for both men and welding equipment during fit-up and welding operations of the erection deck splices. Design drawings are anticipated to incorporate the latter detail.

2.3.10 WELD SYMBOLS -- Rohr Marine has spent numerous hours trying to develop single sided butt welds and has achieved very little success. Two-sided butt welding appears to have the highest rate of success when butt welds are back-gouged and welded from both sides. For this reason designers should not use two-sided square butt symbols on drawings details without specifying back-gouging operations.

2.3.11 INTERFACE FLATBAR (Figure 2-10) -- Design of the Mini-Modules showed the interface flatbar location between deck assemblies is offset such that one edge (interface with frame caps) is only 3/4" above the

deck surface. Frame caps have a butt joint interface with the flatbar after fillet welding operations have been completed. The location of this butt joint is so close to the fillet weld that it is quite difficult to perform, consequently, Production suggested that the flatbar be centered on the deck. To avoid the possibility of the butt weld overlapping the fillet such as has occurred on the mini-module.

2.3.12 FRAME SLOTS (Figure 2-11) -- It was anticipated that during 3KSES construction, frame members would be fabricated as a subassembly prior to installation onto deck assemblies. Frame slots to allow penetration of flatbar stiffeners were called out in detail to provide allowances for easy alignment and fit-up. The width dimension was specified to be 1/8" wider than the flatbar thickness and therefore, allow for some stiffener mislocation or angular offset. It was discovered, however, that the Production Department cut the slots to the fully allowed dimension and in some cases this provided 1/8" gap on one side of thin (.190") flatbar making welding operations difficult. It was determined to reduce the tolerance to a maximum of 1/16" on the width. This tolerance was found to be quite acceptable when fit-up techniques for flatbar layout and welding sequences were used simulating reference dimensioning like that of the panel weld machinery already discussed in Paragraph 2.2.4. To verify this approach, the tolerance was reduced for several panels to be built and frames were fabricated by shop personnel with good success in obtaining easy fit-up.

2.4 PRODUCIBILITY STUDIES

2.4.1 TASK DESCRIPTION -- The task will include an analysis of PHM-1 producibility studies for application to 3KSES and a determination of applicable features that could apply for possible 3KSES structural simplication and producibility improvements.

2.4.2 SUMMARY -- This study continues the evaluation of PHM-1 producibility studies for application to the 3KSES. During this study the longitudinal stringer (rigid haunched flat bar) and the effect of standardizing transverse frame heights were investigated. In addition,

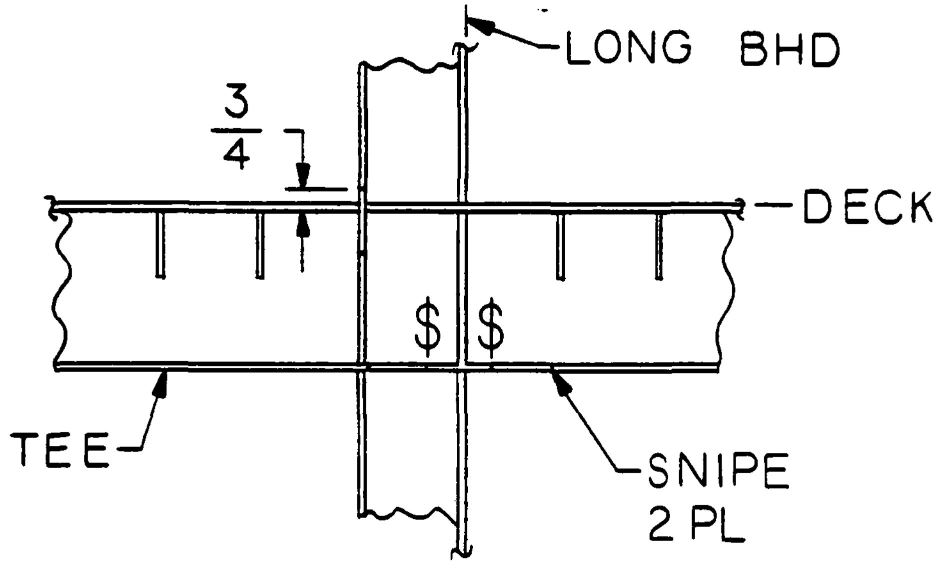


Figure 2-10. Deck Structure Interface Flatbar

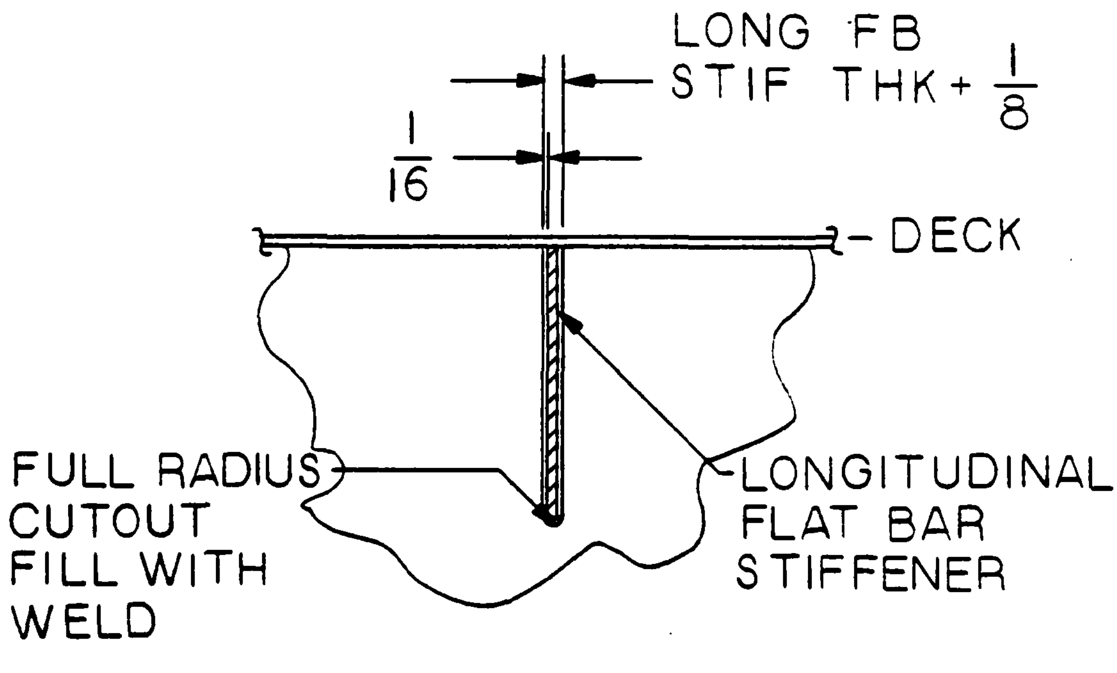


Figure 2-11. Typical Deck Flatbar Penetration through Framing Member

tables have been included in the results section which provide a useful means for comparing direct labor requirements for all alternate longitudinal stringer and inner bottom floor configurations investigated.

Continuity of the producibility study has been maintained by combining the initial and continuing effort into one report as presented herein. Results of these studies form a basis for recommending design changes and identifying areas where further study is necessary or may prove beneficial.

This work is a logical extension of the preliminary design work performed during the Advanced Development Program (102-100). The 3KSES baseline hull structure (Ref. 4) developed during the ADP was used as the reference for comparisons.

Like the PHM-1 lead ship design, the 3KSES baseline design incorporates tee-section longitudinal stiffeners. This stiffener configuration necessitates that a number of complex structural details be specified to ensure design integrity and satisfy closure requirements where web frames and bulkhead are penetrated.

Based upon producibility studies accomplished on the PHM-1 design and our evaluation of the 3KSES design as a part of this study, it was decided to investigate alternate longitudinal stiffener configurations, determine associated structural weights and producibility characteristics, and use these results as a basis for recommending changes to the baseline design.

The alternate longitudinal stiffener configurations investigated in this study are:

a. Straight flat bar
b. Haunched flat bar
    1. Light Weight
    2. Rigid
c. Haunched tee

Except for the haunched tee stiffener, all of the above stiffener configurations represents an increase in structural weight but an improvement in producibility characteristics (e.g., fewer number of simpler parts and improved weld accessibility). The haunched tee stiffener configuration represents a decrease in producibility and an increase in structural weight.

The current 3KSES baseline design incorporates an "I" beam truss floor located between the wet and thrd decks (inner bottom). This design detail is in contrast to the PHM-1 lead ship design and the PHM production design which incorporate stiffened plate girder construction. It was decided that a study in this area might also prove beneficial.

Alternate design configurations investigated include:

a. Tube truss
b. Girder
    (1) *Without transverse flat bars*
        (a) Constant web thickness
        (b) Stepped web thickness
    (2) With transverse flat bars
        (a) Constant web thickness
        (b) Stepped web thickness

The weight superiority of the girder with transverse flat bars and stepped web thickness was demonstrated. However, this design concept involves several more parts than the "I" beam truss design concepts and therefore requires more direct labor hours during manufacture.

In an effort to standardize the transverse frames the feasibility of incorporating constant frame heights for deck, longitudinal bulkhead, sidehull and sidewall frames was evaluated. This producibility concept resulted in a weight increase of approximately 13 long tons as compared to the baseline design.

The detailed results of this study are presented in the following pages. These results are based on preliminary analysis. It is anticipated that more detailed analysis could change numerical results but the trends reported herein would be expected to remain the same.

It is recommended that the study be continued and that the effect of integrating producibility concepts be investigated.

2.4.3 REQUIREMENTS -- The PHM-1 producibility studies (Reference 5) provide a starting point for this study. That study indicated that significant producibility advantage could be realized by incorporating new concepts of design and construction from the PHM-1 baseline design.

In this study the following alternate design considerations were included:

a. Replacing extruded tee longitudinal stiffeners with various flatbar stiffeners.
b. Utilizing stiffened plate more extensively.
c. Standardizing transverse frame heights.

Design loads, stress allowables, factors of safety and hull material selection remained identical to the 3KSES baseline design. In addition, no compromises in structural reliability, maintainability or performance were permitted.

2.4.3.1 Factors of Safety -- The factors of safety used in this study correspond to the requirements for the 3KSES operation previously established (Reference 8). Factor of safety requirements are summarized in Table 2-1.

Table 2-1. Factor of Safety Requirements

Condition	Factor of Safety	
	Yield	Ultimate
Cushionborne Operational	1.3	1.8
Hullborne Operational	1.3	1.8
Miscellaneous (overfill, aircraft landing, dry dock, etc.)	1.3	1.8
Hullborne Emergency	1.0	1.5
Emergency ("V" line, wet deck envelope)	-	1.2

Yield: $FS = F_{yiels}/f_{limit}$

Ultimate: $FS = F_{ultimate}/f_{limit}$

Buckling is treated as an ultimate failure. In all cases, minimum "as welded" material properties were used for structural analysis and design purposes. With the exception of allowing plate yielding for emergency conditions, ultimate strength checks did not consider plasticity. This additional strength inherent in all structures constructed of materials having plastic deformation capability provides a margin of conservatism in addition to that reflected directly by the safety factors.

2.4.3.2 Design Load Conditions -- Table 2-2 summarizes design load conditions (Reference 6) used for this study. These load conditions are the same as those used for the initial sizing of the 3KSES structure. For each load condition, primary load components are combined with local load components to represent specific loading situations the ship is likely to encounter during cushionborne, hullborne, emergency, and miscellaneous modes of operation.

Table 2-2. Design Load Conditions

Condition Number	Condition Description
21	C/B Max Moment
22	C/B Max Torsion
23	C/B Max Accel.
24	H/B Hogging
25	H/B Max Torsion
26	H/B Sagging
201	V-Line
202	Fuel Overfill
203	H/B Hydr. Env.
204	Emerg. Hydr. Env.
205	C/B Hydr. Env.
206	C/B Aircraft Landing
207	Drydocking
208	H/B Max Accel.
209	1.5 FWD/AFT G Combined with 1G Down

2.4.3.3 Material Properties -- Table 2-3 summarizes the minimum mechanical properties for welded 5456 Aluminum Alloy (Reference 8) used in this study. Material "S" allowables were used for the stress analysis in all areas regardless of whether or not welds were located near the area of the analysis.

The yield strength, as used in this report, is determined from a ten inch extensiometer spanning a transverse butt-weld joint. The yield strength indicated by the ten inch extensometer data is closely representative of an effective panel yeild strength and has been adopted for usage by the Aluminum Association (Reference 9). This yield strength has also been substantiated by the H-5 panel testing (Reference 10). When actual ten inch extensometer data (H-5 test program) was used for predicting panel buckling strength, the predicted values closely approximated the actual values, being 1 to 6 percent below the actual strengths.

Table 2-3. Minimum Mechanical Properties for Welded 5456 Aluminum Alloy

Temper	Product and Thickness Range in	Tension		Compression	Shear	
		F_{tu} ksi	F_{ty} ksi	F_{cy} ksi	F_{su} ksi	F_{sy} ksi
-H111	Extrusions	41	24	22	24	14
-H117	Sheet & Plate 0.188 - 1.500	42	26	24	25	15

2.4.4 APPROACH -- The influence of structural arrangement on producibility and structural weight were determined in this study. This section summarizes the approach taken in determining these relationships alternative design configurations considered.

A review of the SNAME report on the PHM-1 producibility study (Reference 5) indicated that significant production cost reductions may be realized by substituting haunched flat bar stiffeners for the tee section stiffeners used throughout the PHM-1 baseline design. The 3KSES baseline design also incorporates tee section stiffeners (Figure 2-12). This study investigated the producibility and structural weight associated with incorporating this type of design approach into the 3KSES baseline design.

The 3KSES Baseline design incorporates an "I" beam truss network (Figure 2-13) for the transverse floor located between the wet and third decks. This approach is in contrast to the PHM-1 lead ship which incorporates stiffened plate girders. This producibility study also investigated this design detail.

The transverse frames of the baseline 3KSES design reflect heights ranging from 8 inches to 15 inches. This study investigated standardizing frame heights throughout the ship. Standardization of the transverse frames contributes to the overall producibility of the hull structure system by reducing the number of welding operations required, increasing welding accessibility, and reducing part inventory and cost.

The existing 3KSES design loads, allowables, and factors of safety were not varied for purposes of this study.

2.4.4.1 Analysis Assumptions -- Basic assumptions established for this trade-off study follow:

a. Structural elastic strains do not exceed the proportional limit.
b. Deflections are small and induce no significant difference in load distribution for the analyzed undeformed structure, and principles of superposition apply.

2.4.4.2 Alternate Stiffener Configurations -- The alternate stiffener configurations included in this study are as follows:

a. Straight flat bar (Figure 2-14).
b. Haunched flat bar (Figure 2-15).
    1. Light weight
    2. Rigid
c. Haunched tee (Figure 2-16)

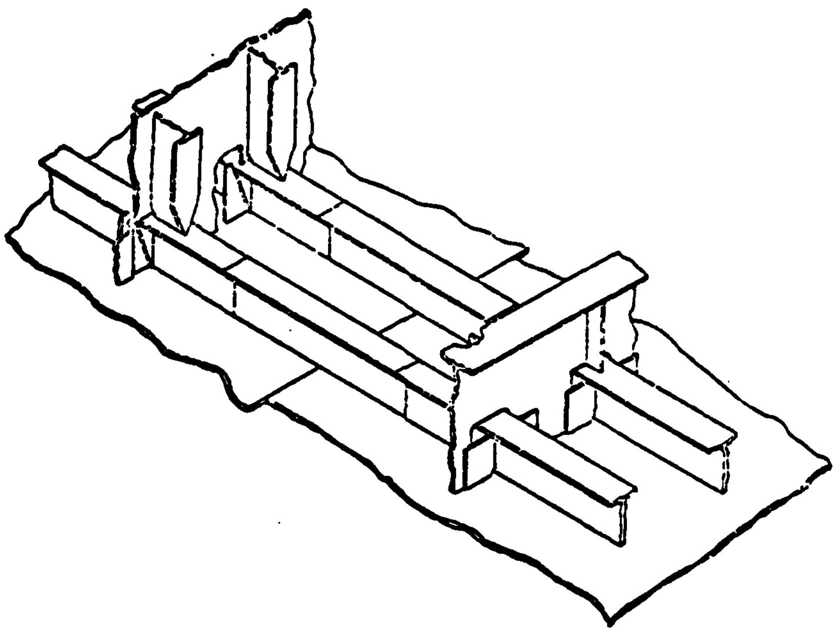


Figure 2-12. Tee Stringer (Baseline)

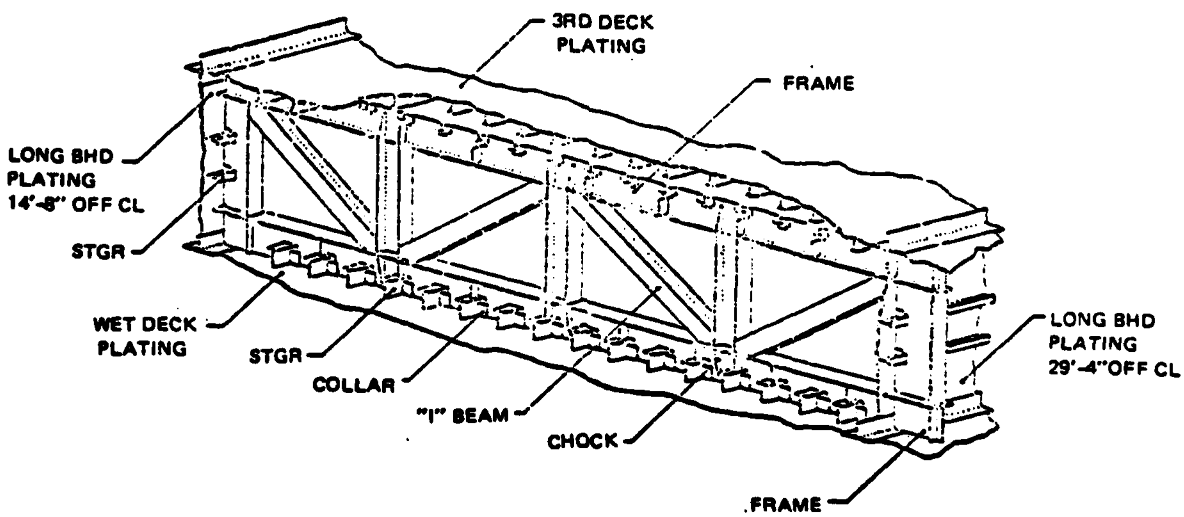


Figure 2-13. "I" Beam Truss (Baseline)

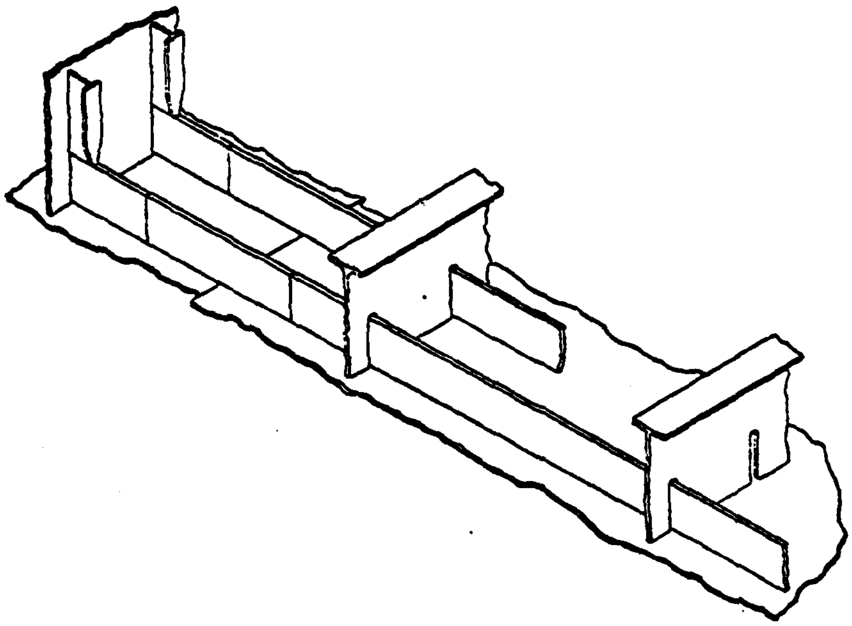


Figure 2-14. Straight Flat Bar Stringer

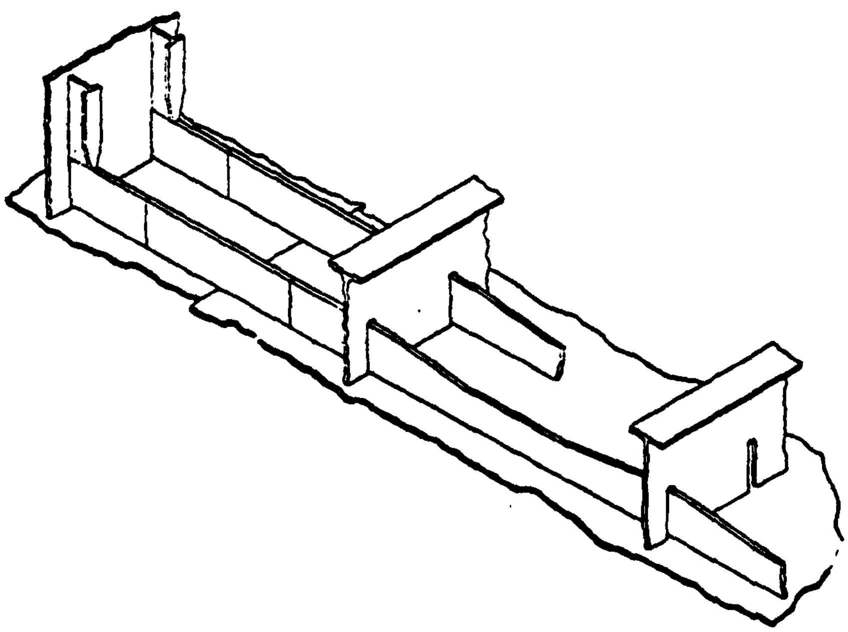


Figure 2-15. Haunched Flat Bar Stringer

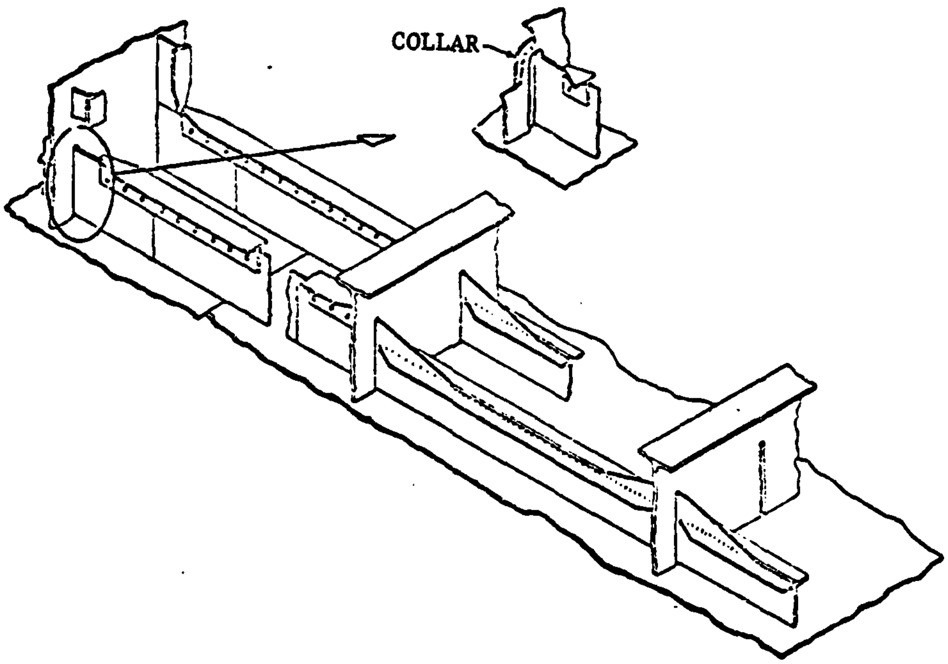


Figure 2-16. Haunched Tee Stringer

Design sketches of typical alternate stiffener configurations included in this study are presented in Appendix C. These stiffener configurations meet extrudability and/or producibility constraints (e.g., welding torch accessibility, etc.).

2.4.4.3 Alternate Inner Bottom Floor Configurations -- Five Alternate structural arrangements were investigated in an effort to improve the producibility of the 3KSES wet deck, third deck "I" beam truss design. A tubing truss alternate is shown in Figure 2-17 and a stiffened plate girder alternate is shown in Figure 2-18. Sketches of all alternate designs investigated are presented in Appendix D.

2.4.4.4 Transverse Frame Height Standardization -- Standard frame heights were selected by reviewing the 3KSES baseline frame heights and selecting the most commonly used heights for standardization purposes. Standard frame heights are presented in Figure 2-19.

2.4.4.5 Methods of Analysis -- Methods of analysis employed were limited to accepted methods documented in textbooks, Navy design data sheets, or published technical articles, The approach was to use high confidence methods of analysis consistent with those methods of analysis developed for the 3KSES during ADP.

To account for the actual fixity present at the ends of stiffeners, mid-span bending moments were calculated on the basis of a multi-span beam analysis. End moments were calculated assuming fixed ends.

The shear compression buckling allowable was calculated based on the method presented in DDS 9110-4 (Reference 11) assuming a uniform axial compression load distribution combined with a uniform shear load distribution. The allowable stress is then compared with the applied stress which consists of applied axial load combined with the secondary effects due to bending. The greater of the mid-span or end plate stress is used when checking for panel buckling. Stiffener and frame web shear/compression buckling is

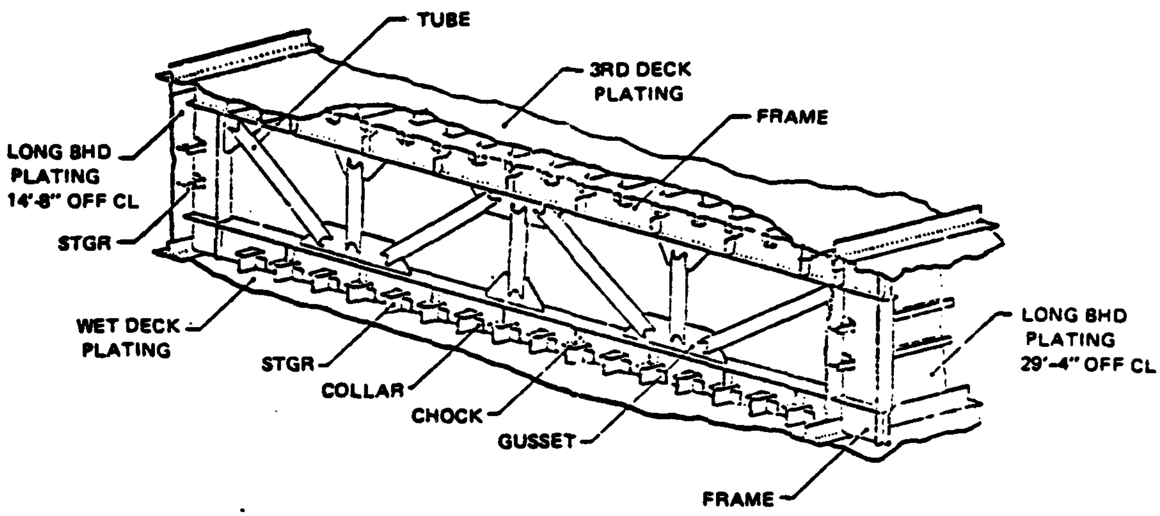


Figure 2-17. Tube Truss (Looking Forward)

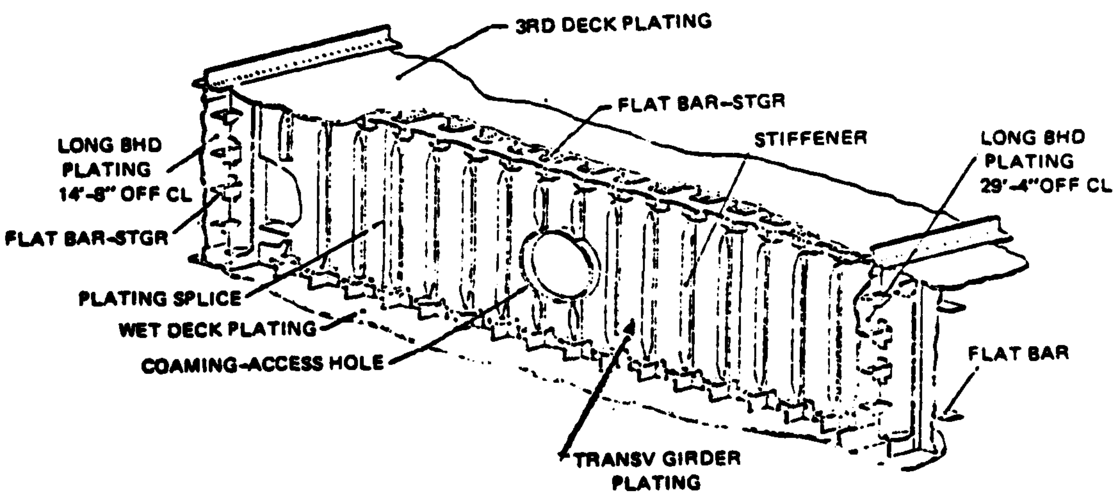


Figure 2-18. Stiffened Plate Girder (Looking Forward)

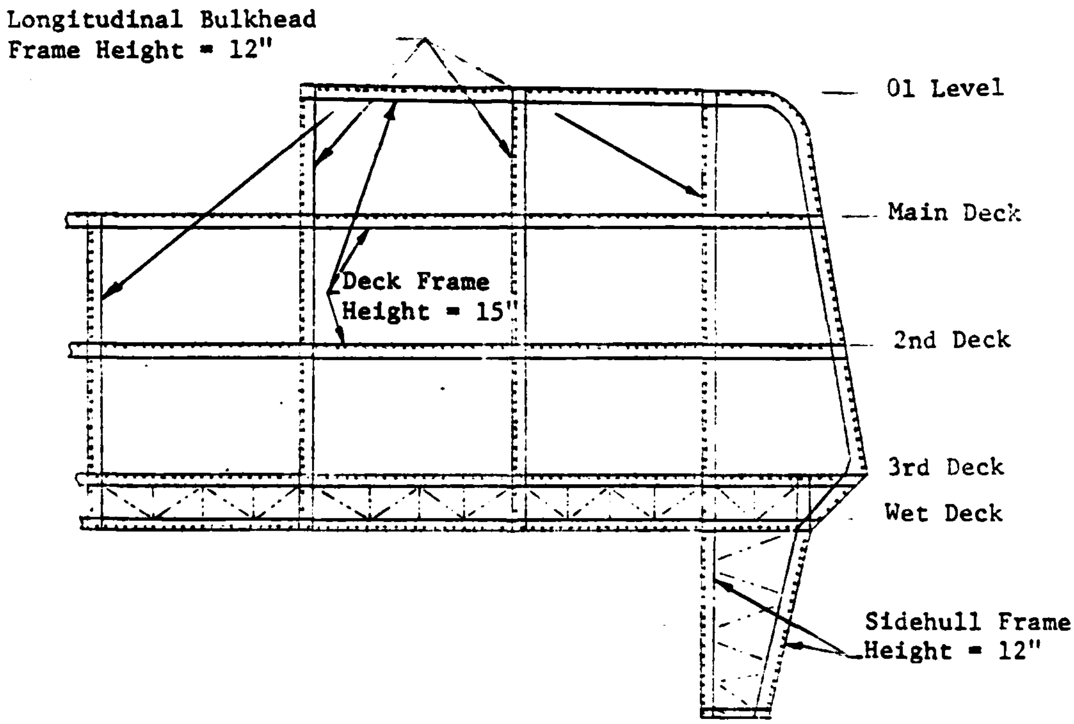


Figure 2-19. Standard Transverse Frame Heights

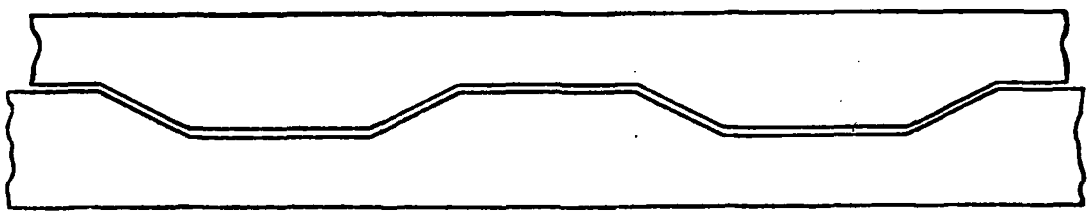
checked at the supports. Uniform pressure distribution is assumed for stiffener and frame moment calculations. This pressure load is considered to be uniformly reacted around the plate's perimeter. This assumption is more conservative than that given by Figure 8 of Reference 11, and is more applicable to plating with the aspect ratios considered in this study.

2.4.4.6 Structural Weight -- Structural weights were determined for each alternate design configuration included in this study. All weight estimates are based upon scantlings determined from the preliminary structural analysis contained herein.

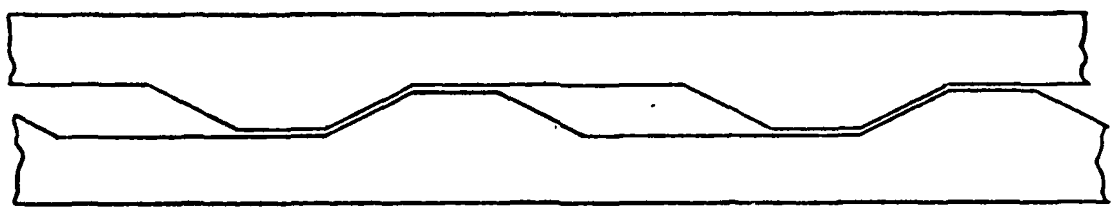
2.4.4.7 Producibility Considerations -- In this study, no attempt was made to provide a specific cost estimate for individual details or the potential cost impact on the total hull construction cost. Rather, study emphasis was placed on improving specific detail producibility characteristics. Detail producibility characteristics (i.e., trends) were established as a function of required manufacturing direct labor hours.

The significant advantage associated with the alternate longitudinal stiffener configurations included in this study is the increased weld accessibility at stiffener-transverse structure intersections and the minimization of complex parts. The baseline tee section intersections are more complex, and reflect less visual and physical access.

The rigid haunched flat bar stringer differs from the light weight haunched flat bar stringer investigated in the initial producibility report in that the haunch length is equal to the unhaunched length. As shown in Figure 2-20, material scrappage is minimized with a rigid stringer configuration and less manufacturing effort is required during fabrication.



Rigid Haunched Flat Bar Stringer



Light Weight Haunched Flat Bar Stringer

Figure 2-20. Rigid Light Weight Haunched Flat Bar Stringer Manufacturing Layout

Although the alternate inner bottom floor configurations included in the study contain more parts than the baseline design, joints associated with the baseline design are more complex. The reduction in joint complexity associated with the alternate inner bottom floor design results in increased structural reliability.

Standardization of the transverse frame heights results in increased producibility for the following reasons:

1. Number of welding operations is reduced.
2. Weld accessibility is increased.
3. Part inventory (and cost) is reduced.

2.4.5 RESULTS -- The results of this producibility study are presented in the following paragraphs. The baseline 3KSES structure was used as the basis for all comparisons. Direct labor hours, as presented in the following sections should be used as indicators only (i.e., labor comparators and not specific labor estimates).

2.4.5.1 Alternate Stiffener Configurations -- The total weight impact for each of the alternate stiffener configurations investigated in this study is presented in Table 2-4. These weights include the stiffened plating and transverse frame modifications required to accommodate the alternate stiffener configurations.

Comparative direct labor hours for the alternate stiffener configurations are presented in Table 2-5. These hours are expressed as a percentage of the baseline configuration direct labor requirement.

Table 2-4. Alternate Stiffener Configuration Weight Impact.

Alternate Stiffener Configuration	Weight Impact (LT)
Straight Flat Bar	+35
Haunched Flat Bar	
Light Weight	+19
Rigid	+21
Haunched Tee	+17

Table 2-5. Alternate Stiffener Configuration Comparative Direct Labor Hour Estimates.

Figure Number	Concept	Direct Labor %* of Baseline	Comment
2-12	Tee Stringer (Baseline)	100%	
2-14	Straight Flat Bar	73%	Simpler than baseline & fewer parts, lends itself to auto. welding of mating trans. bulkheads and much simpler fitting.
2-15	Haunched Flat Bar (Lightweight)	75%	Like above concept additional task of haunching the stringer.
2-15	Haunched Flat Bar (Rigid)	74%	Same as above except material scrappage is minimized.
2-16	Haunched Tee Stringer	125%	Most involved configuration, more fittings, machining, drilling and riveting than baseline.

*NOTE: Percentages noted reflect manufacturing direct labor hours related to stiffener alteration only. No attempt has been made to identify material costs.

2.4.5.2 Alternate Inner Bottom Floor Configurations -- Table 2-6 summarizes the structural weight impact of the alternate inner bottom configurations included within this study. These weights result from applying these concepts to that portion of the ship aft of Frame 14.

Direct labor hours associated with these alternate inner bottom floor configurations are presented in Table 2-7. This data (expressed as a percentage of the baseline configuration labor hour requirement) should be used for comparative purposes only.

Table 2-6. Alternate Inner Bottom Floor Configurations Structural Weight Impact

Alternate Design Configuration	Weight Impact (LT)
Girder w/o trans. flat bar, constant web thickness	+8
Girder w/o trans. flat bar, stepped web thickness	-4
Girder with trans. flat bar, constant web thickness	-2
Girder with trans. flat bar, stepped web thickness	-8
Tube Truss	+14

Note: Refer to Figures D-2 through D-11 in Appendix D for illustrations of the structure referred in table.

Table 2-7. Alternate Inner Bottom Floor Configuration
Comparative Direct Labor Hour Estimate

FIGURE	CONFIGURATION	DIRECT LABOR* (% of Baseline)	COMMENTS
2-13	Baseline "I" Beam Truss	100	
2-17 D-10 D-11	Tube Truss	130	Additional task of cutting angles, slotting ends of tubes, and making gusset plates.
2-18 D-2 D-3	Girder-Const Web w/o trans flat bars	115	Shortness of vertical stiffeners dictates installing as details (manually).
2-18 D-4 D-5	Girder-Stepped Web w/o trans flat bars	119	Variation in web thickness results in additional material handling, cutting, and welding.
2-18 D-6 D-7	Girder-Const Web with trans flat bars	120	Transverse flat bars added.
2-18 D-8 D-9	Girder-Stepped Web with trans flat bar	124	Transverse flat bars added.

*NOTE: Percentages noted reflect direct manufacturing labor hours related to inner bottom alteration only. No attempt has been made to identify material costs.

NOTE: Refer to Appendix D for Figures D-2 through D-11.

2.4.5.3 Transverse Frame Height Standardization -- The weight penalty associated with standardizing the transverse frame height is approximately 13 long tons.

2.4.6 CONCLUSIONS AND RECOMMENDATIONS -- The conclusions and recommendations are based upon the preliminary analysis contained herein. It is anticipated that more detailed analysis could change numerical results but that the relative merits of the concepts evaluated would not change.

2.4.6.1 Conclusions -- The results of the work reported herein indicate that a significant reduction in manufacturing direct labor hours may be associated with the flat bar stiffener configurations. However, weight penalties are also associated with these alternate design concepts. These weight penalties range from approximately 19 LT to 35 LT for the lightweight haunched flat bar and straight flat bar stiffener configurations respectively.

The haunched tee stiffener configuration weighs more than the baseline tee section stiffener and appears to be less producible (i.e., requires more manufacturing direct labor hours).

All alternate inner bottom floor configurations investigated in the study reflect increase in required manufacturing direct labor hours. However, the stepped web girder with transverse flat bars appears promising from a weight and reliability standpoint.

A weight penalty of approximately 13 long tons is associated with the standardization of transverse frame heights. A manufacturing direct labor hour trend was not established for the producibility concept but for reasons presented herein it may be concluded that producibility of the design can be improved if these concepts are incorporated.

All weight determinations and manufacturing direct labor hours presented in this report are preliminary estimates and should only be used as indicators.

2.4.6.2 Recommendations -- The engineering effort associated with this study should be continued. In addition to investigating other areas where producibility studies may prove beneficial, a detailed manufacturing analysis of the design concepts presented herein should be performed in order to better establish each candidate design's producibility/reliability characteristics and provide a firm basis for selecting structural producibility improvements for incorporation into the 3KSES baseline design. It is also recommended that the effect of integrating producibility concepts be investigated.

3 / APPLICATION OF LESSONS LEARNED

3.1 3KSES ENGINEERING PRODUCIBILITY INNOVATIONS

3.1.1 MOLDLINE CHANGE -- The original shell plating moldline was located on the ship's wetted surface (outside); this created a significant production problem at the shell plating gage changes. The gage changes required that each longitudinal shell plating stiffener and transverse frame member be notched and coordinated to accommodate the gap variation because the step causes a change in welding parameters that is not tolerable to automatic aluminum welding. It became quite apparent that a great improvement in producibility could be made by having the moldline on the stiffener side of the plate (a smooth continuous welding surface) and the step on the opposite side away from the stiffeners. This idea was also extended to the decks and longitudinal bulkheads.

3.1.2 FRAME AND LONGITUDINAL BULKHEAD CONNECTION -- The producibility improvement of a relatively simple interface has a very large impact because of the nearly 3000 connections within the ship structure.

The connection originally consisted of a cruciform shaped extrusion (Figure 3-1), that yielded four butt welds that essentially extended the full length of the ship.

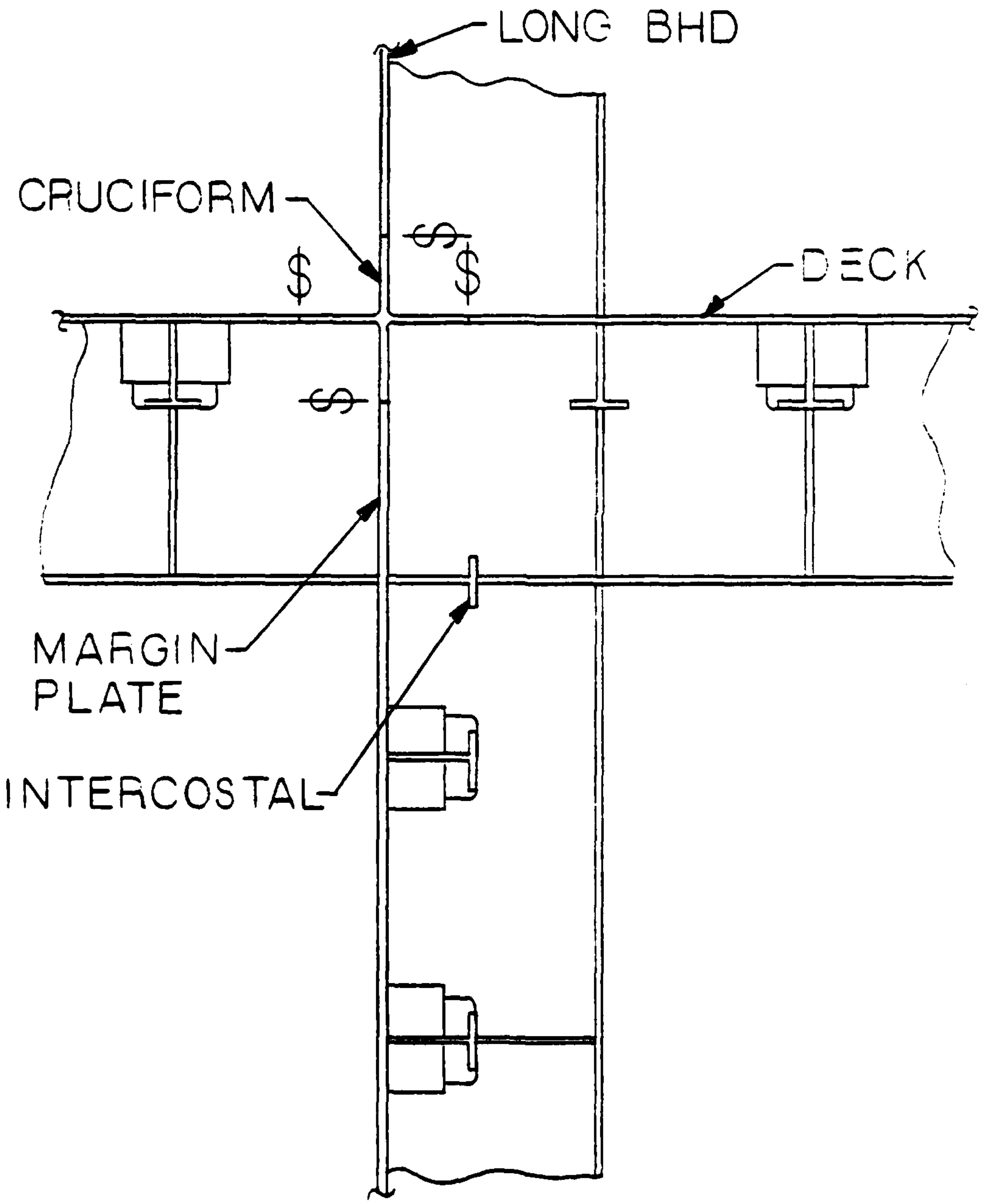


Figure 3-1. Longitudinal Bulkhead and Deck (with Framing) Intersection Utilizing Cruciform Extrusion

The stringent radiographic inspection requirements along with the assembly fit-up problems of long butt welds resulted in a redesign effort to improve producibility. An extruded interface tee (Figure 3-2) replaced the cruciform such that the long butt welds were replaced with readily inspected fillet welds.

Additional benefits were a reduction of linear welding from 1028 linear inches to 664 linear inches per joint per 3 linear feet of ship length (17 miles per ship) and a reduction from 12 to 4 parts per joint (24,000 parts per ship). A very important benefit is the ability to assembly and weld the various joints in a down-hand welding position.

3.1.3 90° TEE TO TEE (WEBS IN PLANE) CORRECTION -- The panelization method of ship construction selected for the 3KSES resulted in the frames being prefabricated to their respective longitudinal bulkheads and deck panels. Therefore as the ship components were assembled a series of 90° tee connections resulted in creating a very difficult butt weld (Figure 3-3) situation that yielded post weld cracks at the interface. The post weld cracking condition was resolved by sniping the transverse frame flange.

A similar problem resulted from the intersection of the diagonal truss members and the transverse deck frames (Figure 3-4) along with a lack of accessibility due to the acute intercept angle. Again the accessibility and weld cracking problems were resolved by sniping the truss flanges.

3.1.4 STRUCTURAL STIFFENERS -- The most efficient structural panel configuration is a flat plate with extruded tee stiffeners welded to a plate (Figure 3-5). The drawback of this configuration was the penetration required by the longitudinal deck stiffeners through each transverse deck frame. On both the tight and non-tight penetrations it requires approximately 100,000 parts to form the collars which introduce additional sources of cracking and corrosion.

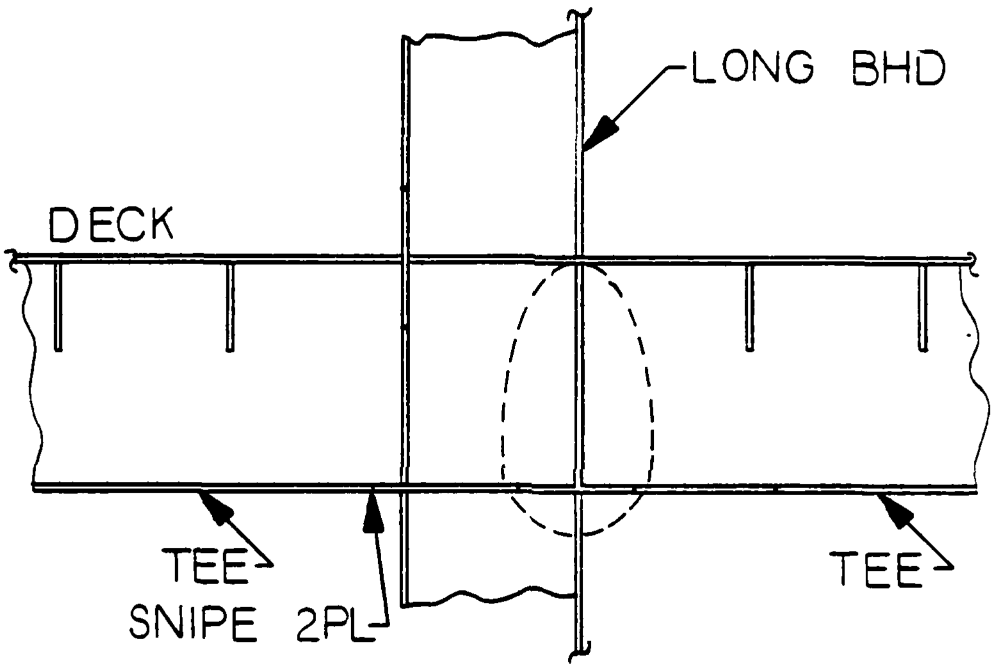


Figure 3-2. Deck Framing Structure Utilizing Interface Tee

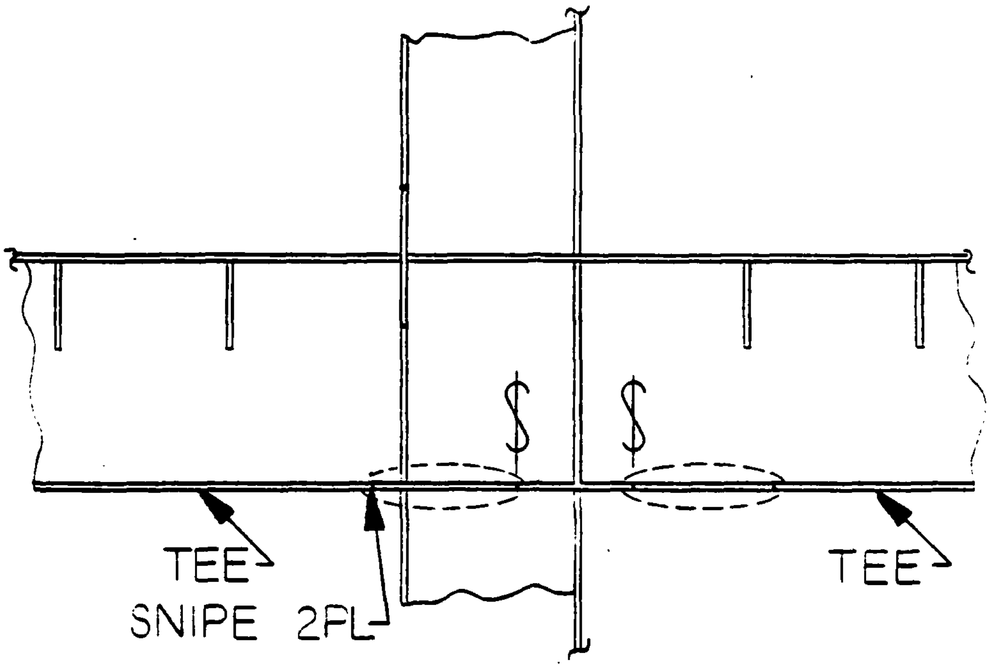


Figure 3-3. Tee to Tee Joint Connection with Tee Flanges Sniped

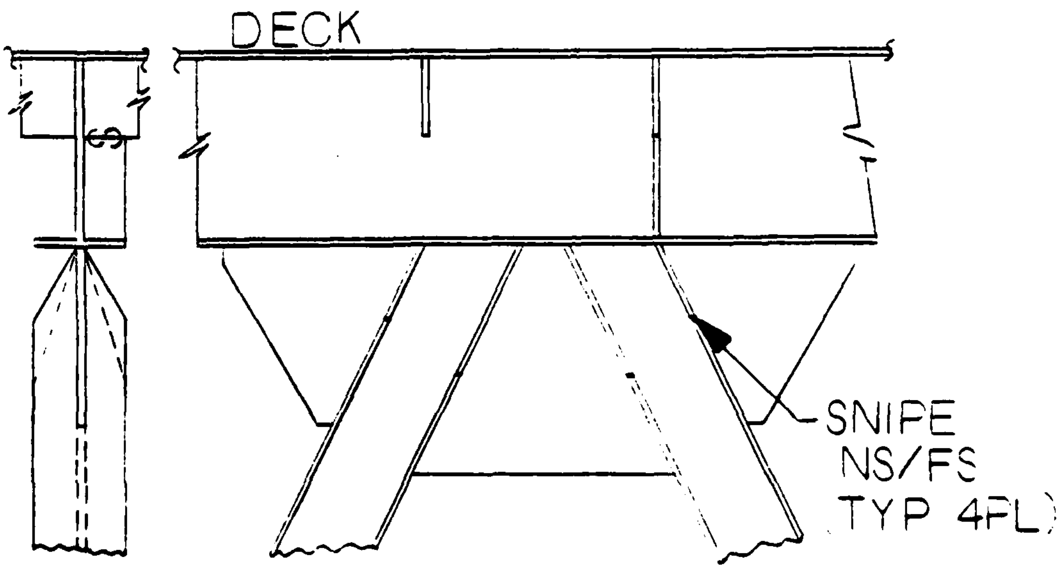


Figure 3-4. Typical Truss Joint with Flanges of I-Section Sniped

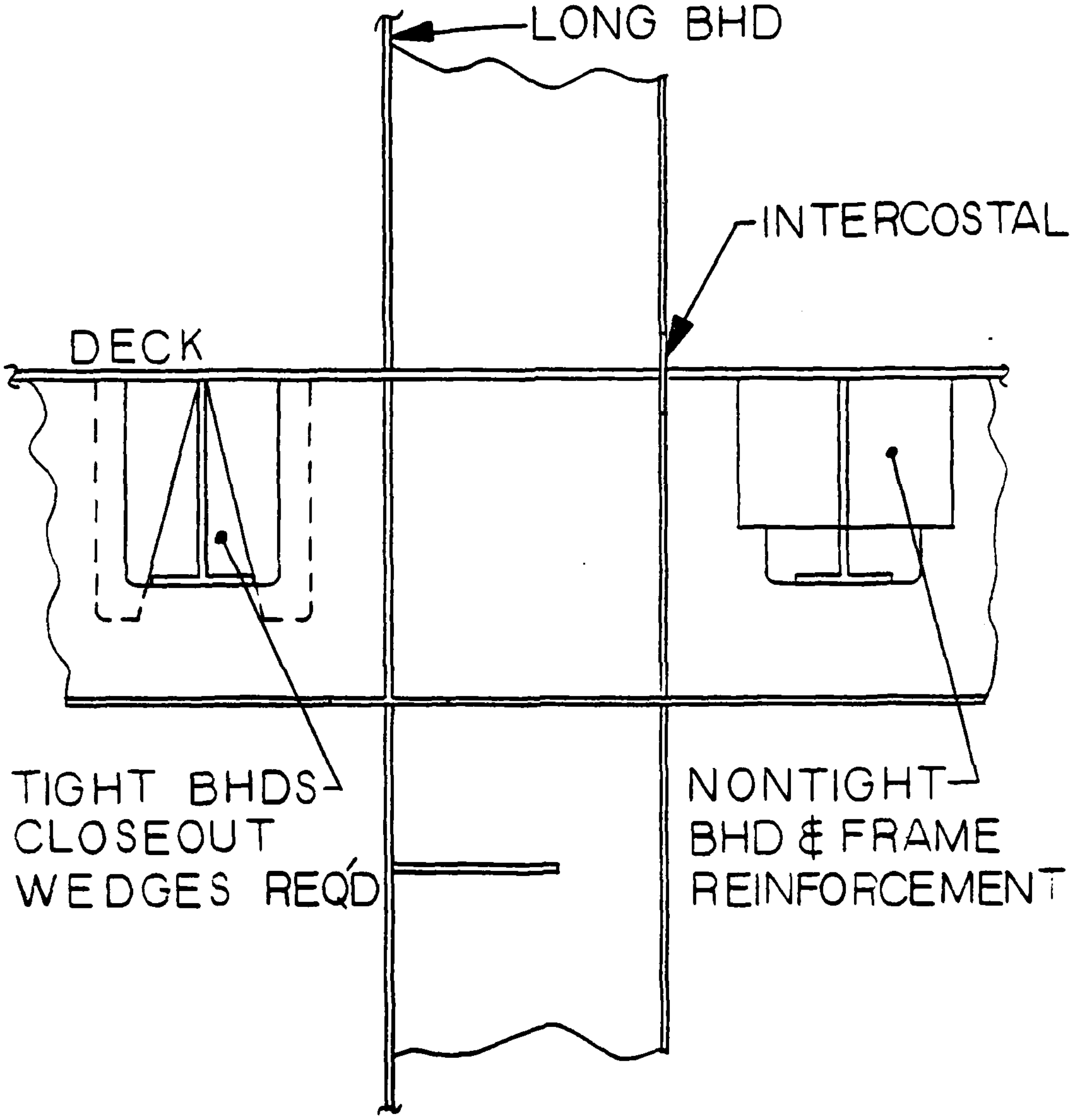


Figure 3-5. Typical Frame with Tight and Non-Tight Penetrations

A structural producibility review resulted in flat bars replacing the extruded tee shapes in order to improve the reliability and producibility; the trade-offs resulted in total shipweight increase of 14 long tons.

An additional benefit was the substitution of individually forming tee stiffeners for the contoured shell areas with contoured cut flat bars.

3.1.5 TRANSVERSE AND VERTICAL INTERFACE TEES -- Producibility improvement includes simplifying shipboard installation of structure. This was accomplished by placing an extruded interface tee between the adjoining structure and all transverse and miscellaneous bulkheads, such that a smooth welding surface was provided by the tee cap. The interface tee became part of the structural frame system and was installed at the deck and longitudinal bulkhead subassembly level allowing longitudinal stiffener penetrations to be completely closed out. This modification reduced the transverse bulkhead to primary structure interface to a unidirectional double fillet weld in place of a similar fillet weld also required to close out longitudinal stiffener penetrations.

3.2 MANUFACTURING LESSONS LEARNED

The various preceeding programs have required considerable manufacturing support and have yielded valuable manufacturing information concerning the limits of forming, fabricating, and welding aluminum. The lessons learned have been summarized as follows:

3.2.1 WELDING SEQUENCE -- Welding sequences have proved to be a key element in fabrication operations in order to minimize distortion. General guidelines for weld sequences have been established and verified through application on the mini-module assemblies. One major discovery during fabrication, however, indicated that weld sequencing of assemblies must take into account the weld sequencing during erection. A clear illustration of this was the examination of welding the longitudinal "T" member to the deck assembly prior to the longitudinal bulkheads being installed. The continuous welds about the "T" caused both the "T" and the

deck to bow out of plane making fit-up and welding problems during bulkhead installation very difficult. The solution to this problem proved to be incrementally welding the "T" to the deck assembly only as required and not welding out completely until the bulkhead has been located, installed and incrementally welded to the "T" prior to weld out operations.

Outer boundaries of welded assemblies should only be welded enough that these boundaries will maintain sufficient flexibility for erection fit-up. Weld-out operations should only occur during the major assembly build-up.

Welding sequence along with assembly build-up and erection sequences are extremely critical functions of the planning stages of welded aluminum structures. It is therefore evident that closer cooperation of the welding engineering group and the planning group must occur in order to minimize the need for distortion removal. This effort proved to be successful during mini-module fabrication and contributed to the success of the finished product.

3.2.2 ERECTION -- Erection plans of the two modules explored the effectiveness of locating bulkheads at the erection site as well as during deck assembly build-up. Both methods proved to be viable approaches and can be used effectively. Deck assembly build-up provides a logical time to locate and install bulkheads with the distinct advantage of downhand welding. The alternate method creates out-of-position welding and should be used only when schedule and space requirements may be limited. This method requires extra time over the former method because of the out-of-position welding and added staging necessary to support welders and their equipment.

3.2.3 CHOCKS AND SMALL BRACKETS -- Chocks and small brackets across interface planes were planned to be installed and welded during the subassembly stage. This proved to be essentially ineffective since in most cases they did not align within tolerance at erection. They also produced unnecessary restraint on the subassembly. Chocks across interface planes installed during erection did not require any additional burdens on production, and should be installed at that point in construction.

3.2.4 DISTORTION REDUCTION -- For reduced distortion, bulkheads and decks should be incrementally welded at interfaces, assembled to its module and then welded out. The additional problems of multiple starts and stops are reduced if welding machines with automatic "crater-fill" functions are used.

3.2.5 PANEL WELDER -- Present automatic panel welding machinery is inadequate for production usage. There is insufficient force available for plate location and stiffener hold downs. There are no seam trackers for butt or fillet welds. There are no methods for locating stiffeners relative to a fixed baseline. A proper panel welder would permit thermal axial growth of the stiffener before the welding torch and would apply a hold-down force behind the torch.

3.2.6 AVOIDING CRACKS DUE TO WELDING -- To avoid cracks when welding large gaps, stringer beads must be laid up on members to reduce the gap <u>before</u> bridging the gap. This reduces the thermal strains hence the stresses across the joint.

3.2.7 MORE EFFICIENT TWO-SIDED BUTT WELDS -- Tungsten arc gouging is faster and more effective than using chipping hammers and groovers when back-gouging for two-sided butt welds. It is silent and can be closely controlled. A trained operator can uncover and observe internal defects more easily than would be obscured when grooving or abrasive gouging.

3.2.8 SINGLE SIDE BUTT WELDS -- Butt weld joints which are essentially one-sided welds with a backing pass on the root side have produced welds with reliable quality and do not have the re-entrant toe angle problem associated with a true one-sided butt weld.

3.2.9 WELDING SEQUENCE -- Baseline weld sequences must be established by Weld Engineering and accurately followed by the Production welding groups to control distortion and locked in stresses.

3.2.10 ERECTION JOINT FITTING -- Plasma arc cutting is an effective tool used during fitting and rework operation. With proper guiding tools, a fitter can remove metal faster and quieter than by the use of saws, drills, mechanical cutters, etc. With correct speed of torch travel, a cut can be made that is ready for welding to the next assembly.

3.2.11 WELD TYPE SEQUENCING -- Where butt welds and fillet welds intersect the butt weld should be welded first, then the fillet welds. This way the butt welds can be inspected without the fillet weld obscuring it, the fillet welded component would also act as a heat sink, preventing proper penetration of the butt weld as it crosses the fillet.

3.2.12 LIFTING AND TURNING -- Lifting and turning provisions, such as pads, lugs, brackets or the actual members left longer and modified for handling must be included on the planning for all decks, bulkheads and their assemblies. This would prevent "jury rigged" fittings and inadequate temporary weldments which may fail during their use. These devices should be designed by structural engineers working in close cooperation with construction planners.

3.2.13 ACCESSIBILITY -- Accessibility requirements for welded details in semi-completed structure should be reviewed and modified. The present example of 3-1/2 inches between deck coamings and bulkhead is too close for effective welding of both members. It is possible that new limited access welding torches may be fabricated for this purpose.

3.2.14 OIL STOPS -- Where there is a fillet weld intersecting a butt weld in the same plane, the fillet weld should be of the full penetration type ("oil-stop") to prevent a less than full penetration butt weld at the intersection of the butt and fillet. This was particularly important at the flat-bar drop-in splices where the flat-bat butt welds intersected the fillet weld which attached the flat-bar to the decks or bulkheads.

3.2.15 TWO SIDED BUTT WELDS WITHOUT BACKGOUGING -- Two-sided square butt welds without back-gouging should not be called out on drawings as they have been impossible for manufacturing to produce in aluminum using the standard GMAW (gas metallic arc welding) process.

3.2.16 TOLERANCES -- Full dimensional tolerances should be shown on the drawings, as required and not be referred back to a general tolerance drawing or the Fabrication Document.

3.2.17 AUTOMATIC WELDING REQUIREMENTS -- It is recommended that for automatic welding of butt welds and fillet welds on a panel welding machine, that a power supply with variable slope control from constant current to constant voltage be used. The panel welding machine will ensure the very precise arc height and travel speed necessary to guarantee high quality welds made using a constant current power supply. It is recommended that for semi-automatic and machine welding that constant voltage gas metal arc welding equipment with a low frequency (120 Hz) pulsed arc be used, the constant voltage feature because of the possibe variations in the torch-to-work height, and the pulsed arc to reduce total amount of heat to the work. Note: Automatic machinery should include: stiffener locating and clamping devices used during welding operations, numerically controlled layout capabilities, and a sufficient plate clamping system.

3.2.18 GAS METALLIC ARC WELDING -- Acceptable, all position fillet weld procedures can be achieved using GMA (Gas Metallic Arc) machine and semi-automatic welding. Precise welding parameters are mandatory to ensure satisfactory weld penetration and elimination of undercutting. The general parameters for the production of aluminum welds are available in literature, manufacturers data and handbooks. These parameters include voltage and amperage settings, pulse frequency and level wire size and feed rate, torch movement rate, skill, etc. When these "textbook" settings are applied to aluminum plates in the sizes chosen for the program, they did not always result in acceptable welds. Changes beyond those considered "fine tuning" of weld procedures are required to produce acceptable and economical welds.

3.2.19 WELD JOINT PREPARATION -- It is recommended that M103 solvent wiping (or equivalent) be utilized in weld joint preparation. The M103 was chosen because of its compatibility with the welding process. It had no residuals, was environmentally safe in a welding arc, unlike trichloroethane which produces a poison gas in welding arc. Stainless steel wire brushing should always be employed immediately prior to the welding operation as it is the most effective practical method of removing oxides which can cause excessive porosity. These oxides form instantly after cleaning when material is exposed to air.

3.2.20 WELD JOINT INTEGRITY -- Control of atmospheric humidity was recommended for subassembly weld fabrication. This was done because the moisture was considered to be the prime cause of porosity in aluminum welds. Later work indicated and confirmed that the mositure which caused the porosity was the water of hydration in the hydrated aluminum oxide on the surface of the joint to be welded and not liquid water on the surface, or the water vapor (humidity) in the air.

3.2.21 WELDING CAPABILITY -- This program has demonstrated a capability to fabricate aluminum alloy structures required for the 3KSES. It has been concluded that conventional GMAW processes using automation

and Wiggler assistance (plus Gas Tungsten Arc Welding for difficult access) can, with precise procedural control, produce high-quality welds with minimal distortion at relatively high production rates.

3.2.22 ALUMINUM WELDING TECHNOLOGY -- Further effort in improving aluminum welding technology should be devoted to optimizing the techniques developed in this program rather than developing advanced processes such as GMA-HFPA, MEBW, etc. (Gas Metallic Arc - High Frequency Pulsed Arc, Mobile Election Beam Welding). The resources, in terms of time and money, that are required to optimize the GMAW process, will provide substantial benefit to all modern high performance ship programs.

3.2.23 RECOMMENDATION -- It must be stressed that, in aluminum welding, precise definition of welding procedures and careful execution in putting the procedures into practice during the welding operation, are required to attain the weld quality necessary for the 3KSES program.

It is recommended that further devleopment effort be continued along the lines established by the Procedural Welding Development Program. Particular emphasis should be placed on the development and evaluation of weld repair techniques (Ref. 3).

3.2.24 WIGGLER -- Subsequent work with the Pacer indicated that there was a superior device for the production of high quality machine assisted fillet welds. This was the Wiggler, produced by MK Co. of Costa Mesa, California. The large rubber drive wheels of the drive mechanism with their 90° axle location prevented slippage and very accurately oriented the arc with respect to the joint. The Pacer with its metallic toothed drive wheel slipped, which affected torch travel rate, and had to be manually oriented to control the torch angle.

3.3 RECOMMENDATION FOR FUTURE PRODUCIBILITY STUDY AREAS -- The weld producibility work done to date has indicated a number of areas which may be fruitful when pursuing further work in the field of complex high-strength, lightweight aluminum weldments:

3.3.1 Automatic programmable panel welding machines similar to the ones in use by Boeing Marine Systems to produce large stiffened panels economically.

3.3.2 Automated inspection techniques associated with the automated welding. Investigations into continuous ultrasonic inspection with real-time readout including defect marking on the joint just welded. This would enable repairs to be made (where required) while the work is still restrained for the original weld.

3.3.3 High-current density (HCD) welding and its application to the welding of thick aluminum plate with minimum joint preparation or beveling. HCD welding has been an accepted technique for producing welds with minimum number of passes, reducing the total heat input and hence distortion.

3.3.4 While it has so far indicated that post-weld peening does not improve a weld beyond the effect of the removal of the weld toe needed to ensure complete peening coverage, it is felt that these are areas in which post weld improvement techniques may be valuable.

3.3.5 Effort should be made to produce welds whose root pass does not have a re-entrant toe angle. Studies have been made that indicate that a TIG root pass, followed by MIG passes can produce acceptable joints without re-entrant toe angles.

3.3.6 Recent work in the field of "weld robotics" has indicated that continuous automatic fillet welding of slotted frames to flatbar stiffened plate is an area that should be studied to determine if it has economic potential.

3.3.7 Future design, producibility, production programs should be aimed toward use of CAD/CAM if economically feasible. Even if there is a design for a one ship program, there is enough repeatability of details to make CAD/CAM work.

3.3.8 Develop effective and economical welded penetrations of pipes, tubes and ducts through decks and bulkheads.

3.3.9 Investigate pre-tensioning of welded members to reduce the effects of post weld distortion.

3.3.10 Study economical methods of installing watertight collars on tee penetrations of bulkheads.

3.3.11 Investigate the use of stud welds to install pipes, insulation, soundproofing wireways, etc.

4 / REFERENCES

1. "Technical Area Development Plan (TADP) (H-5) Hull Structural Systems", CDRL No. S001, 23 October 1974, (Revised 28 February 1975).

2. Welding Procedure Revised, CDRL E014, TTER002-1.

3. Welding and Fabrication Technology Summary Report, CDRL S007 (H-12) 11 June 1976.

4. Structural Drawings

Rohr Drawing No.	Title
LL101004	Extrusions - Structural
LL101005	Tabulation - Plating/Tee
LL110001	Bow Plating & Framing
LL111001	Shell Plating
LL117001	Transverse Frames
LL121001	Bulkhead - Longitudinal, C.L.
LL121004	Bulkhead - Longitudinal, 42' 6" off C.L.
LL122001	Transverse Bulkheads
LL131001	Deck Plating - Main Deck
LL132001	Deck Plating - 2nd Deck
LL133001	Deck Plating - 3rd Deck
LL134001	Deck Plating - Wet Deck
LL136001	Deck Plating - 01 Level
LL159001	Superstructure

5. Bullock, Ottis, R., Oldfield, Brian, Production PHM Design-to-a-Cost Hull Structure, presented at the AIAA/SNAME Advanced Marine Vehicles Conference. September 20-22, 1976.

6. L23100001 "System Specification for the LSES Hull Structure", dated 1 June 1976.

7. CDRL No. C003, LSES Loads and Structures Trade-off Study Report, Rohr Industries, Inc., July 1976.

8. Blaze, Gary C., The 5000-Series Alloys Suitable for Welded Structural Applications, Aluminum Company of America, October 1972.

9. Aluminum Construction Manual, Section 3, Engineering Data for Aluminum Structures, the Aluminum Association, 1972.

10. CDRL No. SOOG(H-5), Hull Structural Systems Panels Test Data Analysis and Correlation Report, Rohr Industries, Inc., March 1976.

11. DDS 9110-4, Strength of Structural Members, Department of the Navy, Bureau of Ships, 7 March 1956.

APPENDIX A

HULL STRUCTURES FABRICATION

PREFACE TO REVISION B

Revision B to this document has been prepared to incorporate changes deemed necessary to clarify, amplify and update the hull structure fabrication requirements preparatory to the start of ship construction. This revision incorporates response to all Navy "Comments on Appendix A of 3KSES Production Plan" transmitted via letter PMS304-23/AM: jdo, Ser 3169, of 17 November 1978. In addition, changes have been made to reflect the findings available from the Structural Panel and Element Test Program, the 3KSES Weld Development Program and on-going structure fabrication efforts. This revision also reflects the revised ship erection sequence described in the Revision A Production Plan TPP001A (CDRL E00K).

Significant revisions incorporated herein include:

1) Added detailed weld sequences for additional structural details and the build-up of a typical major structural assembly.
2) Reflected an increase in the fillet weld design allowable shear strength for joints in type 5456 aluminum made with the 5556 filler material.
3) Revised the table of required joint efficiencies to improve readability and correlation with the 3KSES structural configuration.
4) Added additional production aids and fixtures used for aligning joints to be welded.

The "B" revisions made to this document are indicated by lines placed in the free edge or top margins of all affected pages signifying the extent of change.

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LIST OF TABLES

1 / SCOPE

1.1 INTRODUCTION

This hull structure fabrication document for the 3000 Ton Surface Effect Ship (3KSES) specifies requirements and standards for building practices, materials, weld joint design, workmanship, inspection, acceptance/rejection, weld repairs, and records associated with fabrication of the hull structure. This document includes material from NAVSEA 0900-LP-060-4010 and incorporates modifications to reflect applicable results from the Hull Structure and Manufacturing areas of the SES Advanced Development Program and current work in progress. Portions of other documents referenced in NAVSEA 0900-LP-060-4010 are included to provide a convenient single source of requirements. This fabrication document addresses the requirements of the 3KSES aluminum hull only; therefore, those portions of the NAVSEA -4010 document which apply to other materials are omitted. Requirements in the NAVSEA document which are uniquely critical to aluminum construction, and particularly the 3KSES, are expanded and amplified.

This document fulfills the requirement of Paragraph 3.2.1.4 of the Statement of Work of Contract N00024-77-C-2032 and the applicable requirements of Data Item Description UDI-E-26348A.

1.2 FORMAT

The format of NAVSEA 0900-LP-060-4010 has been adapted for presentation

of the material herein. Section titles, except for Sections 10 and 15, are identical to NAVSEA 0900-LP-060-4010; Section 10 has been expanded to include hull structure materials as well as welding filler materials, and Section 15 presents special requirements for fatigue and fracture control. Paragraphs are numbered sequentially within each section; therefore, correlation of the paragraph numbers in this document with those in NAVSEA 0900-LP-060-4010 is not possible.

1.3 GENERAL

This document contains both mandatory requirements and guidance information. The mandatory requirements are indicated by the words, "will" or "is required" and serve as standards applicable to materials, fabrication, inspection and quality control. Guidance information is indicated by the word "may".

Reference to a particular paragraph or section number of this document includes all applicable subparagraphs under that paragraph or section number. For example, reference to Paragraph 6.5 includes subparagraphs 6.5.1, 6.5.2, etc.

1.4 APPLICABILITY

The provisions of this document are specifically applicable to the 3KSES hull structure and the marine grade aluminum alloys used in its fabrication. Hull structure applications (including the subbases for the lift engine, lift machinery and propulsion machinery) in which materials such as steel or 6061 aluminum alloy are used will be fabricated in accordance with the applicable requirements of MIL-STD-278.

1.5 PRECEDENCE

When approved by NAVSEA, the requirements of this document will supercede any requirements of other referenced specifications, unless otherwise noted herein. In the event of conflict between the requirements of this document and any 3KSES hull structure drawing, the requirements of the drawing will apply; however, approval of the Government Representative is required prior to release of any drawing which relaxes requirements contained in this document.

2 / APPLICABLE DOCUMENTS

2.1 GENERAL

The following documents of the exact issue shown form a part of this document to the extent specified herein. In the event of conflict between these documents, as referenced herein and the contents of this document, the contents of this document shall be considered a superseding requirement. In the event of conflict between Rohr Marine, Inc. (RMI) documents, as referenced herein, and the other documents referenced herein, the contents of the RMI documents shall be considered a superseding requirement.

Unless otherwise specified:

a. The effective issue of lower tier documents referenced by the following documents shall be that issue in effect on the issue date of the referenced document. This method of establishing effective issues shall be used at all subsequent tier levels.

b. If a document appears at more than one tier level, the issue to be used at all levels shall be that issue at the highest tier. This shall be established independently for each requirement specified herein.

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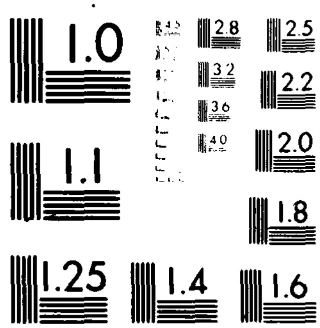


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

2.2	GOVERNMENT DOCUMENTS	
2.2.1	SPECIFICATIONS	
2.2.1.1	Federal	
BB-H-1168	Rev. B 9 May 1977	Helium, Technical.
HH-I-595	Rev. C 9 Apr. 1976	Insulation Tape, Electrical, Pressure Sensitive Adhesive, Plastic.
QQ-A-200/4	Rev. C 21 August 1970	Aluminum Alloy Bar, Rod, Shapes, Tube, and Wire, Extruded, 5083.
QQ-A-200/6	Rev. D 17 Sept. 1970	Aluminum Alloy Bar, Rod, Shapes, Tube, and Wire, Extruded, 5454.
QQ-A-200/7	Rev. D 17 Sept. 1970	Aluminum Alloy Bar, Rod, Shapes, Tube, and Wire, Extruded, 5456.
QQ-A-250/10	Rev. D 9 Dec. 1970	Aluminum Alloy 5454 Plate and Sheet.
QQ-A-250/20	31 Dec. 1968	Aluminum Alloy 5456 Plate and Sheet for Sea Water Applications.
TT-P-645	12 Apr. 1962	Primer, Paint, Zinc Chromate, Alkyd Type.
2.2.1.2	Military	
MIL-I-8950	Rev. B 7 July 1950	Inspection, Ultrasonic, Wrought Metals; Process for.
MIL-Q-9858	Rev. A 16 Dec. 1963	Quality Program Requirements.
MIL-W-10430	Rev. B 25 August 1965	Welding Rods and Electrodes, Preparation for Delivery of.
MIL-P-15328	Rev. D 21 Apr. 1978	Primer (Wash), Pretreatment Formula No. 117 for metals.
MIL-P-15930	Rev. B 13 Apr. 1970	Primer, Coating, Shipboard, Vinyl-Zinc Chromate Formula No. 120 - For Hot Spray.
MIL-E-16053	Rev. L, Amend. 1 1 August 1974	Electrodes, Welding, Bare, Aluminum Alloys.

MIL-C-18255	Rev. D 21 Oct. 1968	Calking Compound, Synthetic Rubber Base, Wooden Deck Seam Application.
MIL-A-18455	Rev. B 20 Mar. 1962	Argon, Technical.
MIL-S-24149	Rev. A, Suppl. 1 11 Oct. 1967	Studs, Arc Welding, and Arc Shields (Ferrules): General Specifications.
MIL-S-24149/2	Rev. B 20 Oct. 1972	Studs, Aluminum Alloy for Direct Energy Arc Welding and Arc Shields (Ferrules).
MIL-I-25135	Rev. C 1 June 1964	Inspection Material, Penetrant.
MIL-I-45208	Rev. A 16 Dec. 1963	Inspection System Requirements.
2.2.2	STANDARDS	
2.2.2.1	Federal	
FED. STD. NO. 123	Rev. D 22 Jan. 1975	Marking for Domestic Shipment (Civilian Agencies).
FED. STD. NO. 184	Rev. A 23 Dec. 1966	Identification Marking of Aluminum, Magnesium and Titanium.
FED. STD. NO. 245	Rev. D. 31 July 1972	Tolerances for Aluminum Alloy and Magnesium Alloy Wrought Products.
2.2.2.2	Military	
MIL-STD-002 SHIPS	Rev. B 8 May 1969	Welded Joint Design.
MIL-STD-248	Rev. C 12 Oct. 1973	Welding Procedure and Performance Qualification.
MIL-STD-271 SHIPS	Rev. E 31 Oct. 1973	Nondestructive Testing Requirements for Metals.
MIL-STD-278 SHIPS	Rev. E 29 March 1976	Fabrication Welding and Inspection; and Casting Inspection and Repair for Machinery, Piping and Pressure Vessels in Ships of the United States Navy.
MIL-STD-418	Rev. C 15 June 1972	Mechanical Tests for Welded Joints.

MIL-STD-649	Rev. C 7 June 1976	Aluminum and Magnesium Products - Preparation for Shipment and Storage.
MIL-STD-1628	28 June 1974	Fillet Weld Size, Strength, and Efficiency Determination.

2.2.3 NAVY PUBLICATIONS

NAVSHIPS 0900-014-6010	Not Dated	Naval Terminology Manual.
NAVSEA 0900-LP-060-4010	Change 1 1 July 1975	Fabrication, Welding and Inspection of Metal Boat and Craft Hulls.
NAVSEA 0901-LP-920-0003	1 Aug. 1971	Naval Ships Technical Manual - Chapter 9920 Welding and Allied Processes.

2.3 NON-GOVERNMENT DOCUMENTS

2.3.1 SPECIFICATIONS

T23100001B	15 Dec. 1978	3KSES Hull Structure Specification (CDRL E01F).

2.3.2 TECHNICAL SOCIETY PUBLICATIONS

2.3.2.1 American National Standards Institute (ANSI)

ANSIH35.2-1975	22 Nov. 1976	Standard Dimensional Tolerances for Aluminum Mill Products.

2.3.2.2 American Welding Society

AWS A2.4-76	14 August 1975	Symbols for Welding and Nondestructive Testing.
AWS A3.0-76	14 Nov. 1975	Welding Terms and Definitions

2.3.2.3 American Society for Nondestructive Test (ASNT)

SNT-TC-1A	June 1975	Recommended Practice for Nondestructive Testing Personnel Qualification and Certification.
McMaster, R.C.	1959	Nondestructive Testing Handbook (Ronald Press Co.).

2.3.3 ROHR MARINE INCORPORATED DOCUMENTS

TQPP001B	30 June 1978	3KSES Quality Program Plan (CDRL No. E012)

TPP00016A	8 Feb. 1978	Structural Panel Test Plan (CDRL No. E064).

3 / DEFINITIONS

3.1 GENERAL

Except as noted herein, welding nomenclature and definitions conform to A.3.0-76 "Welding Terms and Definitions" published by the American Welding Society, 2501 N.W. 7th Street, Miami, Florida 33125.

Except as noted herein, nondestructive testing nomenclature and definitions conform to the "Handbook of Nondestructive Testing of the American Society for Nondestructive Testing, 914 Chicago Avenue, Evanston, Illinois 60602.

Except as noted herein, nomenclature of common ship parts conform to NAVSEA 0900-LP-014-6010, "Naval Terminology Manual".

3.2 NOMENCLATURE AND DEFINITIONS

ACCEPTABLE. Complies with or conforms to the applicable standard or specification.

ACCEPTABLE WELD. A weld that meets all the design and service requirements and the acceptance criteria prescribed by this document.

ACTIVITY. The physical plant of an organization performing work to which this standard is applicable.

APPROVAL (APPROVED). The item under consideration requires formal acceptance by NAVSEA or its authorized representative. Approval (or approved) as used herein shall be by the authorized representative unless otherwise specified. See GOVERNMENT REPRESENTATIVE.

ARC STRIKES. Any inadvertent change in the contour of the finished weld or adjacent base metal resulting from an arc or heat generated by the passage of electrical energy between the surface of the finished weld or base metal and a current source, such as welding electrodes or magnetic inspection prods.

AUTOMATIC WELDING. Welding with equipment which performs the welding operation without adjustment of the controls by a welding operator. The equipment may or may not perform the loading and unloading of the work. See MACHINE WELDING.

BACK GOUGING. The removal of weld metal and base metal from the other side of a partially welded joint to assure complete penetration upon subsequent welding from that side.

BACKING. A material (base metal, weld metal, or nonmetallic) placed at the root of a weld joint for the purpose of supporting molten weld metal.

BACKING BAR. A bar placed at the root of a weld joint for the purpose of supporting molten weld metal. It may either become integral with the weld by intent, or may be deliberately removed.

BACKING PASS. A pass made to deposit a backing weld.

BACKING STRIP. Backing in the form of a strip.

BACKING WELD. Backing in the form of a weld.

BACK WELD. A weld deposited at the back of a single groove weld.

BAR. A solid member that is long in relation to cross-section, which is square, rectangular or a regular polygon with at least one perpendicular distance between parallel faces equal to 5/8 inch or greater.

BASE METAL (MATERIAL). The metal (material) to be welded, formed or cut.

BLOCK WELD. An increment of a continuous multiple pass weld that is completely or partially built up in cross-section before adjacent lengths are deposited.

BURN-THRU. Excessive melt-thru or a hole. See MELT-THRU.

BUTT. A transverse or vertical plate edge connection in shell, bulkhead, or deck plating. See SEAM.

BUTTERING or BUILDUP. The deposition of filler metal on a base metal surface to restore base material or weld surface dimensions, or to interpose a layer of weld metal on the joint prior to joining the material members together. See also CLADDING, COATING and SURFACING.

BUTT JOINT. A welded joint between two members aligned approximately in the same plane.

CERTIFICATION. (1) A declaration that an instrument is accurate within specified limits based on comparison with a traceable standard. (2) A declaration in writing that a statement is true.

CLAD METAL. A composite metal containing two or three layers that have been welded together. The welding may have been accomplished by roll welding, arc welding, casting, heavy chemical deposition, or heavy electroplating. See CLADDING, SURFACING.

CLADDING. A relatively thick layer (greater than 0.04 in.) of material applied by surfacing for the purpose of improved corrosion resistance or other properties. See also COATING, and SURFACING.

COATING. A relatively thin layer (less than 0.04 in.)of material applied by surfacing for corrosion prevention or other purposes. See CLADDING, SURFACING.

CLOSURE PLATES. Plates welded into an essentially completed structure for purposes such as closing an access opening or installing the final shell plate.

COALESCENCE. The growing together or growth into one body of the materials being welded.

COAMING. Plate(s) at the periphery of a deck or bulkhead opening normal to the plane of the opening.

COMPLETED WELD. Welding is completed, plating has cooled to ambient temperature, and the weld has been visually inspected and accepted, and is ready for other NDT inspection as required.

COMPLETE FUSION. Fusion which has occurred over the entire base material surfaces intended for welding, and between all layers and passes.

COMPLETE JOINT PENETRATION. Joint penetration in which the weld metal completely fills the groove and is fused to the base metal throughout its total thickness.

CONSUMABLE INSERT. Preplaced filler metal which is completely fused into the root of the joint and becomes part of the weld. See also BACKING.

CRACK. A fracture-type discontinuity characterized by a sharp tip.

CROWN. See preferred term FACE REINFORCEMENT.

DCAS/QAR. The Defense Contract Administrative Service Quality Assurance Representative. See also APPROVAL and GOVERNMENT REPRESENTATIVE.

DEFECT. A discontinuity or discontinuities which by nature or accumulated effect render a part or product unable to meet minimum applicable acceptance standards or specifications. This term designates rejectability. See DISCONTINUITY, FLAW.

DEFECTIVE WELD. A weld containing one or more defects.

DEPTH OF FUSION. The distance that fusion extends into the base metal or previous pass from the surface melted during welding.

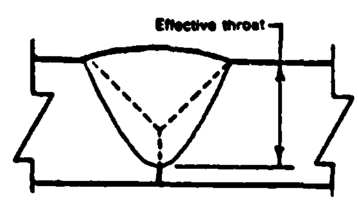
DESTRUCTIVE TEST. (DT) The testing of an element, component, or assembly using techniques which destroy or impair the servicibility of the part to determine the compliance of the part with strength or other specified characteristics. (This term is synonomous with destructive inspection, evaluation or examination).

DISCONTINUITY. An interruption of the typical structure of a weldment, such as a lack of homogeneity in the mechanical, metallurgical or physical characteristics of the material or weldment. A discontinuity is not necessarily a defect. See DEFECT, FLAW.

DROP-THRU. (1) An undesirable sagging or surface irregularity, usually encountered when welding near the melting point of the base metal caused by overheating. (2) The visible root reinforcement (i.e. suspended bead) produced in a complete joint penetration for a joint welded from one side. See MELT-THRU.

DRUM HEADING. A fabrication technique used for distortion control where the peripheral edges of the plate are secured to rigid temporary structure before welding.

EFFECTIVE THROAT. The minimum distance from the root of a weld to its face less any reinforcement. See also JOINT PENETRATION.



ERECTION. The assembly of various parts, subassemblies, and major assemblies of the hull on building ways or in the building dock.

EXTRUSION. A form or shape produced by pushing material through a die.

FABRICATION. The act of shaping, assembling, and securing in place the component parts in order to form a subassembly, assembly, erection unit or complete ship.

FABRICATION DOCUMENT. The document which contains the minimum requirements for building practices, standards for materials, weld joint design, workmanship, inspection, and record keeping associated with fabrication of a product and is designated as such in the product specifications. For example, this document (when approved) is the fabrication document for the 3KSES.

FACE REINFORCEMENT. Reinforcement of weld at the side of the joint from which the welding was performed. See also REINFORCEMENT OF WELD and ROOT REINFORCEMENT.

FAYING SURFACE. That surface of a member which is in contact with another member to which it is to be joined.

FILLER METAL (MATERIAL). The metal (material) to be added in making a welded joint.

FILLET WELD. A weld of approximately triangular cross-section joining two surfaces approximately at right angles to each other in a lap joint, T-joint or corner joint.

FINISHED WELD. Welds which have received final inspection and have been accepted.

FISSURE. A small crack-like discontinuity with only slight separation (opening displacement) of the fracture surfaces. The prefixes macro or

micro indicate relative size.

FLAT POSITION. The welding position used to weld from the upper side of the joint; the face of the weld is approximately horizontal.

FLAW. A synonym for defect; for example, a discontinuity with the connotation of rejectability. See DEFECT, DISCONTINUITY.

FLUX. Material used to prevent or dissolve oxides and other undesirable surface substances or facilitate their removal.

FORMING-COLD. Operations which form the part by plastic deformation at temperatures below the material recrystallization temperature.

FORMING-HOT. Operations which form the part by plastic deformation at temperatures above the material recrystallization temperature.

FUSION. The melting together of filler metal and base metal or of base metal only, which results in coalescence. See DEPTH OF FUSION.

FUSION FACE. A surface of the base metal which will be melted during welding.

FUSION WELDING. Any welding process or method which uses fusion to complete the weld.

FUSION ZONE. The area of base metal melted as determined on the cross-section of a weld.

GAS METAL ARC WELDING (GMAW). An arc welding process which produces coalescence of metals by heating them with an arc between a continuous filler metal (consumable) electrode and the work. Shielding is obtained entirely from an externally supplied gas or gas mixture. (This process has sometimes been called MIG welding, a nonpreferred term.)

GAS TUNGSTEN ARC WELDING (GTAW). An arc welding process which produces coalescence of metals by heating them with an arc between a tungsten (non-consumable) electrode and the work. Shielding is obtained from an externally supplied gas or gas mixture. Pressure may or may not be used and filler metal may or may not be used. (This process has sometimes been called TIG welding, a nonpreferred term.)

GOVERNMENT INSPECTOR (REPRESENTATIVE). Government official who is charged with the responsibility for assuring that the materials, processes, fabrication technique and testing personnel meet specification and contractual requirements. In this regard, the official may be:

a. The Supervisor of Shipbuilding or the Supervisor's delegated representative.

b. The cognizant Government representative or the representative of another Government agency designated by or through the cognizant Government representative.

GROOVE. An opening or channel in the surface of a part or between two components which provides space to contain a weld.

GROOVE WELD. A weld made in the groove between two members to be joined. The standard types of groove welds are as follows:

Square

V	J	Single or double
Flare V	Bevel	
U	Flare Bevel	

HEAT-AFFECTED ZONE. That portion of the base metal which has not been melted, but whose mechanical properties or microstructure have been altered by the heat of welding or cutting.

HORIZONTAL POSITION. As related to a fillet weld, the position in which welding is performed on the upper side of an approximately horizontal surface and against an approximately vertical surface. As related to a butt weld, the position of welding in which the axis of the weld lies in an approximately horizontal plane and the face of the weld lies in an approximately vertical plane.

HULL STRUCTURE. For the purposes of this document, the hull structure will be construed to include those portions of the structure which maintain the water-tight integrity of the hull including the shell, structural bulkheads, framing, decks and platforms. Additionally, the hull structure will include foundations, sidehull fences, stabilizer fins, weight-handling fittings, access trunks, masts, superstructure, and waterjet inlets. See also PRIMARY HULL STRUCTURE AND SECONDARY HULL STRUCTURE.

INADEQUATE JOINT PENETRATION. Joint penetration which is less than that specified.

INCOMPLETE FUSION. Fusion which is less than complete.

INDICATION. Objective evidence which marks or denotes the presence of a discontinuity; term usually used in inspection (other than visual) as a synonym for discontinuity.

INERT GAS. A gas which does not normally combine chemically with the base metal or filler metal. See also PROTECTIVE ATMOSPHERE.

INSERTS. Inserts are those parts welded into the hull structure, or other structural area by some type of butt joint to reinforce the structure at openings or areas of high stresses. Inserts may be of the same or

greater thickness than the surrounding structure. See also CONSUMABLE INSERT.

INSPECTOR. Designated contractor or Government agency employee qualified, as required by this document, and authorized to accept or reject materials and workmanship and to witness tests and validate test data.

INTERPASS TEMPERATURE. In a multiple-pass weld, the temperature of the metal at the site of operations before the next pass is started.

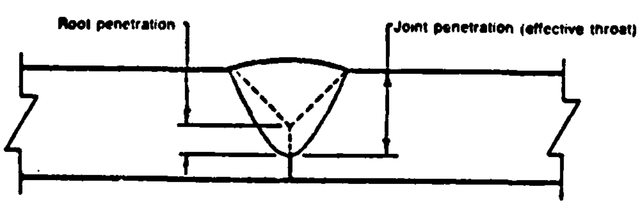
JOINT. The junction of members or the edges of members which are to be joined or have been joined.

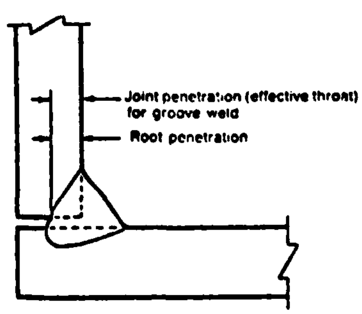
JOINT DESIGN. The joint geometry together with the required dimensions of the welded joint.

JOINT EFFICIENCY. Weld joint efficiency is the strength of welded connection expressed as a percentage of the specified strength of the base material (see Sec. 11). For mechanically fastened joints, see Section 16.

JOINT GEOMETRY. The shape and dimensions of a joint in cross-section prior to welding.

JOINT PENETRATION. The minimum depth a groove or flange weld extends from its face into a joint, exclusive of reinforcement. Joint penetration may include root penetration. See also COMPLETE JOINT PENETRATION, ROOT PENETRATION, AND EFFECTIVE THROAT.





JOINT WELDING PROCEDURE. The materials, detailed methods and practices employed in the welding of a particular joint.

LACK OF FUSION. See preferred term INCOMPLETE FUSION.

LACK OF JOINT PENETRATION. See preferred term INADEQUATE JOINT PENETRATION.

LAP JOINT. A joint between two overlapping members.

LEG OF FILLET WELD. The distance from the root of the joint to the toe of the fillet weld.

LIQUID PENETRANT. A method of nondestructive examination which provides for the detection of discontinuities which are open to the surface of the material.

MACHINE WELDING. Welding with equipment which performs the welding operation under the constant observation and control of a welding operator. The equipment may or not perform the loading and unloading of the work. (Welding with accessory units, such as the Pacer™ and Wiggler™, which control the lead angle and rate of travel when held by the operator against the work, is considered machine welding.) See AUTOMATIC WELDING and SEMI-AUTOMATIC WELDING.

MANUAL WELDING. A welding operation performed and controlled completely by hand. (GTAW with a hand held welding gun and hand fed filler, if used, is considered manual welding).

MARGIN PLATE. A plate designed to be added at the time of erection to correct discrepant materials or deviations in construction.

MATERIAL CERTIFICATION. A certified document, provided by the supplier or mill/foundry, stating that the material constituents fall within the ranges specified by the applicable material specifications.

MATERIAL TEST REPORT. An analysis, provided by the supplier or mill/ foundry, of the chemical and physical properties of the material.

MELT-THRU. Complete joint penetration for a joint welded from one side. A visible root reinforcement is produced.

METHOD. An orderly arrangement or set form of procedure to be used in the application of welding or allied processes.

MIG WELDING. See preferred term GAS METAL ARC WELDING.

NAVSEA APPROVAL. The item under consideration requires formal acceptance by the Naval Sea Systems Command. See PMS304.

NAVSEA AUTHORIZED REPRESENTATIVE. For the purpose of this document, the Government representative authorized to approve matters such as equipment, material and procedure qualification data within the scope of this standard for NAVSEA. See PMS304.

NONDESTRUCTIVE EXAMINATION (NDE). The examination of an element, component or assembly by methods that do not destroy or impair the servicibility of the part to determine its suitability for use.

NONDESTRUCTIVE INSPECTION (NDI). Same as NONDESTRUCTIVE EXAMINATION.

NONDESTRUCTIVE TESTING (NDT). Same as NONDESTRUCTIVE EXAMINATION.

OUT-OF-POSITION-WELD. A general term used to denote any position of welding other than the FLAT POSITION.

OVERHEAD POSITION. The position in which welding is performed from the underside of the joint.

OVERLAYING. See preferred term SURFACING.

PACER™. A particular type of self propelled accessory machine for making butt-welds with a semi-automatic GMAW gun. The unit fixes the attitude of the gun in a hand-guided carriage and electronically controls the rate of travel under the constant observation and control of a welding operator.

PARTIAL JOINT PENETRATION. Joint penetration which is less than complete. See also COMPLETE JOINT PENETRATION.

PASS. A single progression of a welding or surfacing operation along a joint, weld, deposit, or substrate. The result of a pass is a weld bead, layer, or spray deposit.

PATCHES. Patches are sections of plate installed to replace other materials or to correct discrepant materials or errors in construction. Patches are normally joined to other plating members by butt-welds.

PENETRATIONS. Penetrations are those members or components, such as stiffeners, pipe or trunks, welded into the hull structure or other components by a grooved-tee or fillet weld. Penetrations pass through the structure and extend beyond one or both sides of the structure.

PLASMA ARC CUTTING (PAC). An arc cutting process which severs metal by melting a localized area with a constricted arc and removes the molten material with a high velocity jet of hot, ionized gas issuing from the orifice.

PLATE. A rolled product rectangular in cross-section and form of thickness 0.250 inch or more.

PMS304. The directorate of NAVSEA assigned management responsibility of the SES project.

POSITION OF WELDING. See FLAT, HORIZONTAL, VERTICAL, AND OVERHEAD POSITIONS.

POSITIONED WELD. A weld made in a joint which has been so oriented as to facilitate making the weld.

POROSITY. Cavity type discontinuities formed by gas entrapment during weld solidification. See WORMHOLE POROSITY.

PREHEAT TEMPERATURE. A specified temperature that the base metal must attain in the welding, brazing, soldering, thermal spraying or cutting area immediately before these operations are performed.

PRIMARY HULL STRUCTURE. For the purposes of this document, the hull structure which makes up the primary hull girder. It includes the strength decks, shell plating and their supporting framing, sidehulls and fences, main longitudinal bulkheads and main transverse bulkheads. All fluid tight bulkheads, foundations designed for major equipment, and vital spaces will also be considered as primary hull structure.

PROCEDURE. A written instruction covering fabrication operations such as welding, cutting, or inspection, and containing all of the applicable essential elements (with prescribed values or ranges of values) required by this document.

PROCEDURE QUALIFICATION. The demonstration that the operation(s) performed in accordance with a specific procedure can meet prescribed standards.

PROCESS. A distinctive progressive action, or series of actions, involved in the course of producing a basic type of result. See WELDING PROCESS.

PROTECTIVE ATMOSPHERE. A gas envelope surrounding the part to be welded or thermal sprayed, with the gas composition controlled with respect to chemical composition, dew point, pressure, flow rate, etc. Examples are inert gases and vacuum. See also INERT GAS.

QUALIFICATION. See preferred terms WELDER PERFORMANCE QUALIFICATION and WELDING PROCEDURE QUALIFICATION.

QUALIFIED. The item under consideration has been approved as required by this document.

REINFORCEMENT OF WELD. Weld metal in excess of the quantity required to fill a joint. See also FACE REINFORCEMENT and ROOT REINFORCEMENT.

RE-ENTRANT ANGLE. A re-entrant angle occurs when the angle formed between the base plate and weld, at the weld edge, is less than 90°.

RESIDUAL STRESS. Stress remaining in a structure or member as a result of thermal or mechanical treatment or both. Residual stress arises in fusion welding primarily because the melted material contracts on cooling from the solidus to room temperature.

RIGGING FITTINGS. Fittings used with material handling devices such as kingposts, cranes, booms, lifting pads, and cleats.

ROD. A solid member that is long in relation to cross section, which is 3/8 inch or greater in diameter.

ROOT OF JOINT. That portion of a joint to be welded where the members approach closest to each other. In cross-section the root of the joint may be a point, a line or an area.

ROOT OF WELD. The point(s), as shown in cross-section, at which the back of the weld intersects the base metal surfaces.

ROOT OPENING. The separation between the members to be joined at the root of the joint.

ROOT PENETRATION. The depth that a weld extends into the root of a joint

measured on the centerline of the root cross-section.

ROOT REINFORCEMENT. Reinforcement of weld at the side other than that from which welding was done. See also REINFORCEMENT OF WELD and FACE REINFORCEMENT.

SEAM. A fore-and-aft or horizontal plate-edge connection in the shell, deck, or bulkhead plating.

SEAL WELD. Any weld designed primarily to provide a specific degree of tightness against leakage.

SECONDARY HULL STRUCTURE. All of the hull structure which is not included in the primary hull structure.

SEMIAUTOMATIC WELDING. Welding with equipment which controls only the filler metal feed. The gun attitude and advance of the welding is manually controlled.

SHAPE. A wrought product that is long in relation to its cross-sectional dimensions and has a cross-section other than that of sheet, plate, rod, bar, tube, or wire.

SHEET. A rolled product rectangular in cross-section and form of thickness 0.006 through 0.249 inch.

SHRINKAGE VOID. A cavity type discontinuity normally formed by shrinkage during solidification.

SHRINK WELD. A weld bead made on a plate surface to reduce distortion caused by previous welding.

SLAG. Non-metallic solid material entrapped in the weld metal or between weld metal and base metal.

SURFACING. The deposition of filler metal (material) on a base metal (substrate) to obtain desired properties or dimensions. See also BUTTERING, CLADDING and COATING.

TACK WELD. A weld made to hold parts of a weldment in proper alignment until final welds are made.

TAILED POROSITY. A crack-like extension of a pore or wormhole.

TEMPORARY SNIPE. A small snipe or opening in an abutting member to permit the deposition of a sound weld in a joint passing above or beneath the abutting member.

TUBE. A hollow wrought product that is long in relation to its cross-section, which is round, a regular polygon, elliptical, square or rectangular with sharp or rounded corners, and that has uniform wall thickness except as affected by corner radii.

UNDERCUT. A groove melted into the base metal adjacent to the toe or root of a weld and left unfilled by weld metal.

UNDERFILL. A depression on the face of the weld or root surface extending below the surface of the adjacent base metal.

VERIFY (VERIFICATION). For the purposes of this document, this term will mean examination of records such as test results for the purpose of determining compliance with applicable specification requirements.

VERTICAL POSITION. The position of welding in which the axis of the weld is approximately vertical.

WELD. A localized coalescence of metals or nonmetals produced either by heating the materials to suitable temperatures, with or without the application of pressure, or by the application of pressure alone, and with or without the use of filler material.

WELD BEAD. A weld deposit resulting from a pass. (See PASS).

WELDER. One who performs a manual or semiautomatic welding operation. (Sometimes erroneously used to denote a welding machine). See also WELDING OPERATOR.

WELDER CERTIFICATION. Certification in writing that a welder has produced welds meeting prescribed standards.

WELDER PERFORMANCE QUALIFICATION. The demonstration of a welder's ability to produce welds meeting prescribed standards.

WELDING MACHINE. Equipment used to perform welding operations.

WELDING OPERATOR. One who operates machine or automatic welding equipment. See also WELDER.

WELDING PROCEDURE QUALIFICATION. The demonstration that welds made by a specific procedure can meet prescribed standards.

WELDING PROCESS. A materials joining process which produces coalescence of materials by heating them to suitable temperatures, with or without the application of pressure or by the application or pressure alone, and with ot without the use of filler metal.

WELDING SEQUENCE. The order of making the welds in a weldment.

WELDING TECHNIQUE. The details of a welding procedure which are controlled by the welder or welding operator.

WELDMENT. An assembly whose component parts are joined by welding.

WELD METAL. The portion of a weld which has been melted during welding.

WELD REINFORCEMENT. See preferred term REINFORCEMENT OF WELD.

WIGGLER^{TM}. A particular type of self-propelled accessory machine for making fillet welds with a semi-automatic GMAW gun. The machine fixes the attitude of the gun in a hand-guided carriage and electronically controls the rate of travel under the constant observation and control of a welding operator.

WIRE. A solid wrought product that is long in relation to its cross-section, which is round, square or rectangular with sharp or rounded corners or edges or a regular polygon, and whose diameter or greatest perpendicular distance between parallel faces (except for flattened wire) is less than 3/8 inch.

WORMHOLE POROSITY. Gas inclusions having an elongated form known as "wormholes" or "pipes" usually almost perpendicular to the weld surface.

WROUGHT PRODUCT. A product which has been subjected to mechanical working by such processes as rolling, extruding, forging, etc.

4 / QUALIFICATION REQUIREMENTS

4.1 SCOPE

This section covers the minimum requirements for qualification of welding procedures, welders, welding operators, non-destructive test procedures, and non-destructive test personnel for fabrication and inspection of the 3KSES hull structure.

4.2 GENERAL

4.2.1 PURPOSE -- The purpose of these qualification requirements is to ensure that proven fabrication and non-destructive test procedures are used with adequate equipment by properly trained personnel.

4.2.2 BACKGROUND -- The qualification requirements specified herein are based on compliance with those requirements in NAVSEA 0900-LP-060-4010 which are applicable to the fabrication and inspection of the aluminum alloy hull structure. Modifications and amplifications which reflect experience gained during the SES Advanced Development Program and the SES-100A1 modification are incorporated. Where departures from pre-existing requirements, acceptance standards, and specifications have been incorporated in this document, these departures generally augment and clarify the original requirements, and, in some cases, increase the stringency of such requirements.

4.2.3 RESPONSIBILITY AND CONTROL -- It is the responsibility of the Contractor to perform all required qualification tests to the satisfaction of the Government Representative prior to the start of production work. Qualification tests will be performed in accordance with the requirements in this section.

Welding and fabrication processes, procedures, equipment and materials other than those specified in this document may be used in hull structural applications only if the prior approval of NAVSEA (or its authorized representative is obtained. (See Paragraph 1.4 of this document regarding ancillary structures). Requests for deviation will provide technical justification, i.e., mechanical test data, corrosion data, weldability and/or procedure qualification tests.

4.3 WELDING PROCEDURE QUALIFICATION

Welding procedure qualification will be accomplished for each combination of base material, filler metal and welding process as they apply to the 3KSES hull structure.

Procedure qualification requirements will be as specified in MIL-STD-248 except as modified and amplified herein. Requirements from MIL-STD-248 are identified by the applicable MIL-STD-248C paragraph number shown in parentheses following the paragraph titles in this section.

4.3.1 SCOPE (4.1) -- This section provides the requirements for the qualification of welding procedures to be used in fabrication of the 3KSES hull structure. Qualification requirements are provided for categories as follows:

a. General - groove welds and fillet welds used in butt, corner, tee and lap joints.

b. Welding on bare surfaces.

c. Seal and pipe socket welds.

d. Stud welding.

Other categories of welds, as identified in MIL-STD-248 , are not planned for use in the 3KSES hull structure.

4.3.2 GENERAL REQUIREMENTS

4.3.2.1 Responsibility (4.2.1) -- The Contractor will prepare written welding procedures and conduct the appropriate tests to qualify these procedures including demonstration of repeatability.

4.3.2.2 Certification of Procedures (4.2.2) -- The Contractor will certify by signature of a delegated authority that tests to qualify each procedure have been performed in conformance with the requirements of this section. The delegated authority will be a member of the Quality Assurance Group designated in writing by the Group Manager, Quality Assurance. The Government Representative will be advised of the delegation of certification authority, and may, at his option, also certify the weld procedures.

4.3.2.3 Submittal for Approval (4.2.3) -- Qualification data for welding procedures will be prepared and certified as specified in paragraph 4.3.6.1 below and submitted in accordance with the Contract Data Requirements List (CDRL). NAVSEA approval of welding procedure qualification data will be obtained prior to use of the procedure in production welds.

4.3.2.4 Vendor Qualification (4.2.4) -- The Contractor will assure that all subcontractors assigned work on the 3KSES hull structure have qualified weld procedures based on approved qualification data.

4.3.2.5 Waiver of Qualification (4.2.6) -- All hull structure welding will be performed with qualified procedures.

4.3.2.6 Qualification Levels (4.2.7)

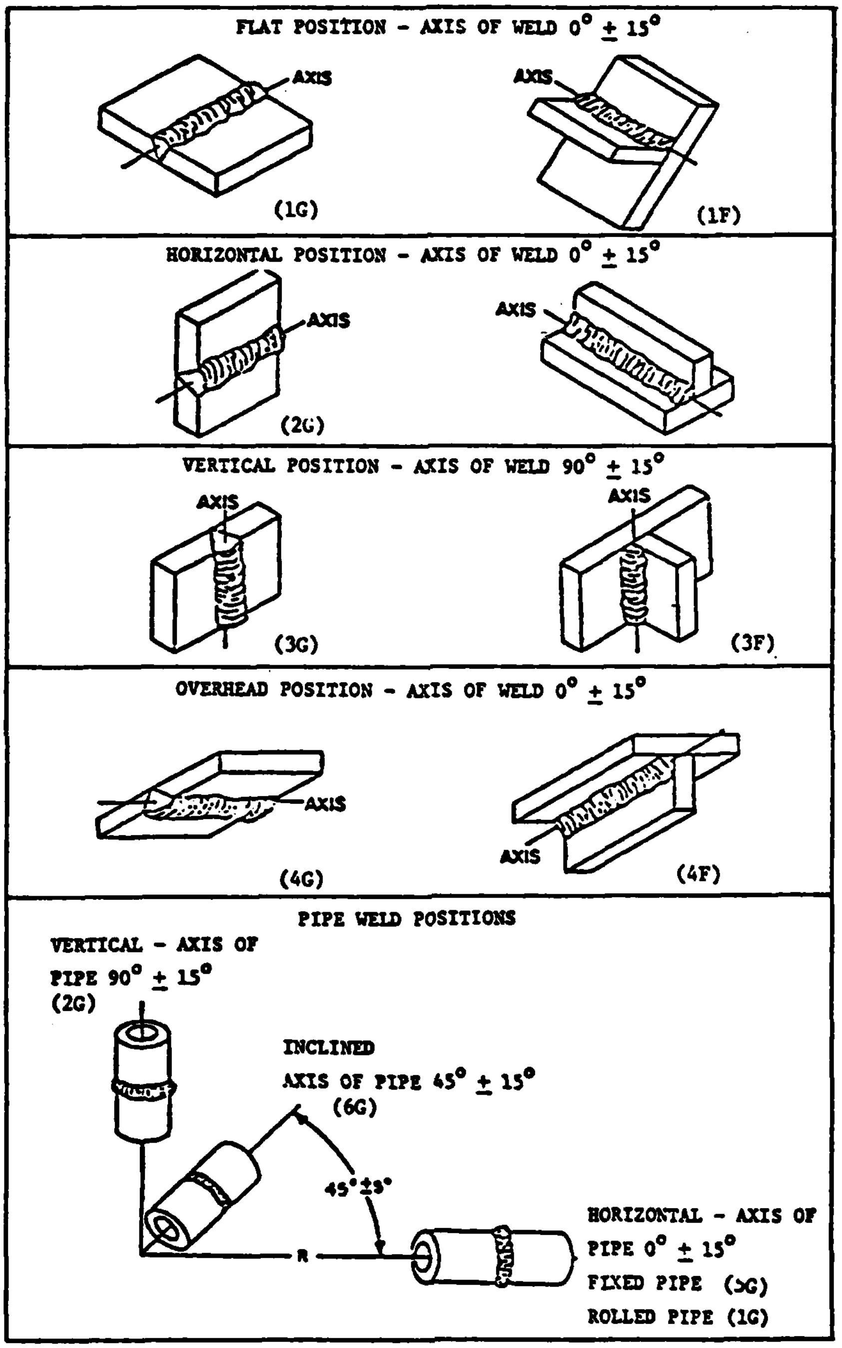
4.3.2.6.1 Level No. I (4.2.7.2) -- This qualification level covers the initial qualification of any welding procedure for the fabrication welding of wrought or cast aluminum for the 3KSES hull structure. Approval of the required Level No. I procedure qualifications will be obtained from NAVSEA as specified in paragraph 4.3.2.3 above. This qualification level covers any welding procedure to be qualified by the evaluation of procedure qualification weld assemblies as defined below in paragraph 4.3.5. Qualification of the procedures for fabrication welding will also qualify for repair welding within the limits of the qualified procedure. Qualification tests will qualify for welding positions as specified below in paragraph 4.3.2.7, and thickness ranges as specified in paragraph 4.3.4.1.5.

4.3.2.6.2 Level No. II (4.2.7.3) -- This qualification level permits procedure approval for a variation in a procedure, as outlined below in paragraph 4.3.8, which has already been qualified by qualification Level No. I. Plate test assemblies will be used for Level II qualification tests of butt welds, and at least 15 inches of the weld will be radiographically inspected. Approval of the required Level No. II procedure qualifications will be obtained from NAVSEA as specified in paragraph 4.3.2.3.

4.3.2.7 Welding Position Qualification Limits (4.2.8) -- The orientation of positions of welding procedure qualification test assemblies will be classified by reference to the positions shown on Figure 4-1. Procedure qualification test assemblies welded in a given position will be used to qualify the procedure as shown in Table 4-1.

4.3.2.8 Repair of Test Assembly (4.2.9) -- Test assemblies for procedure qualification will not be repair welded.

4.3.2.9 Transferal of Welding Procedure Qualification (4.2.10) -- Requalification of a previously qualified Contractor procedure will not be required when this procedure is used in any of the Contractor's



1. Excerpted from MIL-STD 248C.
2. Flat positions are established as 0° reference plane for axis of weld.
3. Rotation of the weld face ± 15° about the axis of the weld does not change the classification of the welding position.

Figure 4-1. Positions of Welding.

Table 4-1 - Procedure Qualification Position Limitations.
(Excerpted from Table IV, MIL-STD-248C)

Forms of base material qualified	Positions to be qualified (grooves & fillets) (build-up & buttering)	Positions used during qualification (see Figure 4-1)	
		Using Plate ⚠1	Using Pipe ⚠2
Plate, castings, forgings, and shapes	All positions	Vertical and overhead positions ⚠3	
	Flat and vertical	Vertical position	
	Flat and horizontal	Horizontal position	
	Flat and overhead	Overhead position	
	Flat Horizontal fillets only	Flat position	
Pipe	All positions		Horizontal and vertical-fixed pipe positions
	Horizontal-fixed pipe position and horizontal rolled pipe position		Horizontal-fixed pipe position
	Vertical-fixed pipe position and horizontal rolled pipe position		Vertical-fixed position
	Horizontal-rolled pipe position		Horizontal-rolled pipe position

⚠1 Weld procedures for plate, castings, forgings and shapes will be qualified using plate test assemblies.

⚠2 Weld procedures for pipe will be qualified using pipe test assemblies.

⚠3 For semi-automatic gas metal-arc welding using the spray transfer or pulsed spray transfer process, the horizontal position must also be run to qualify for all positions.

facilities. However, welders or welding operators will have been trained in the use of such procedure before it is used in production work, and the welding equipment will be capable of reproducing the essential parameters of the approved procedure.

4.3.3 WRITTEN WELDING PROCEDURE CONTENT (4.3) -- Welding procedures (except for stud welding) developed for qualification and use on the 3KSES hull structure will include the applicable essential elements listed in Table 4-2. The essential elements will be included, along with pertinent elements in a Contractor Welding Procedure Qualification Data and Test Report, a typical example of which is presented in Figure 4-2.

4.3.4 SPECIFIC QUALIFICATION REQUIREMENTS (4.4) -- This paragraph provides specific requirements for test assembly design, size, orientation, and methods of evaluation for qualification of welding procedures.

4.3.4.1 Groove welds (4.4.1)

4.3.4.1.1 Base Material (4.4.1.1) -- Qualification test assemblies will be made using base materials procured to the applicable specifications referenced in the procedure. Use of alternate materials of the same alloy type or grade will be made only with the concurrence of the Government Representative.

4.3.4.1.2 Test Assembly Size (4.4.1.2) -- The test assembly will be as shown in Figure 4-3 for plate, castings, forgings and shapes and in Figure 4-4 for pipe and tubing. Test assemblies produced to the requirements of Figure 4-3 will not be shorter than specified to ensure stabilization of procedure parameters. The test assembly defined in Figure 4-3 has been modified from that shown in MIL-STD-248C in order to provide two test specimen areas in each assembly.

Table 4-2 - Essential Elements of 3KSES
Hull Structure Welding Procedure
(Excerpted from Table V, MIL-STD-248C)

Element	Arc Welding		
	Manual (GTAW)	Semi-Automatic (GMAW)	Automatic & Machine (GMAW)
Base Material - Specification and type or class, thickness and condition	X	X	X
Filler Material - Specification, type, diameters	X	X	X
Applicable Joint Design - Dimensional sketch	X	X	X
Process - Gas metal arc (GMAW), gas tungsten arc (GTAW)	X	X	X
Machine, Model or Type	NA	X	X
Electrical Characteristics - Current, arc voltage range, polarity	X*	X	X
Travel Speed	NA	NA	X
Filler Material Feed Rate	NA	NA	X
Position (including progression vertical up or down)	X	X	X
Torch Type	X	X	X
Torch Shielding Gases - type, mixture, flow rates	X	X	X
Interpass Temperature Limits	X	X	X
Torch Oscillation - Amplitude and frequency	NA	NA	X
Torch Position - (Relative offset from vertical centerline in horizontal rolled position)	NA	NA	X
Electrode Lead or Trail Angle (wire feed angle)	NA	NA	X
Gas Cup Size	X	X	X

NA = Not Applicable

*Except for arc voltage

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WELDING PROCEDURE QUALIFICATION DATA AND TEST REPORT

☐ PLATE
☐ EXTRUSION
☐ PIPE

DATE: ____________
CONTROL NO.: ____________
PROCEDURE NO.: ____________

WELDER/OPERATOR ____________
WELDER IDENTIFICATION NO. ____________

POWER SUPPLY ____________
TYPE METAL TRANSFER ☐ GAS METAL ARC SPRAY ☐ PULSED SPRAY

WELDING PROCEDURE

BASE MATERIAL

SPECIFICATION ____________
TYPE-TEMPER ________ GAGE ______ / ______
CLASSIFICATION ☐ S22 ☐ S25 ☐ ______ (OTHER)
CLEANING PROCESS ____________

FILLER MATERIAL

SPEC ________ TYPE ________ DIA. ________

TORCH TYPE ____________
TORCH POSITION* ____________
TORCH OSCILLATION* ____________
ELECTRODE LEAD/TRAIL ANGLE* ____________
CURRENT/POLARITY ________ CUP SIZE ________
SHIELDING GAS ______ % ARGON ______ % HELIUM
GASFLOW RATE ________ CFM
INTERPASS TEMPERATURE LIMITS ____________
TRAVEL SPEED* - (IPM): ____________

HIGH ______ LOW ______ ACTUAL ______

AMPERAGE:

HIGH ______ LOW ______ ACTUAL ______

VOLTAGE:

HIGH ______ LOW ______ ACTUAL ______

*For automatic or machine processes only.

PROCESS: ☐ GMAW ☐ GTAW

☐ AUTOMATIC
☐ MACHINE
☐ SEMIAUTOMATIC
☐ MANUAL (GTAW ONLY)

JOINT DESCRIPTION

WELD POSITION

☐ GROOVE ☐ FILLET

☐ FLAT ☐ VERTICAL (UP) ☐ HORIZONTAL ☐ OVERHEAD

PIPE AXIS ORIENTATION:

☐ VERTICAL ☐ HORIZONTAL ☐ INCLINED

QUALIFICATION TESTS (PASS/FAIL)

VISUAL	TENSILE ULTIMATE
PENETRANT	TENSILE YIELD
RADIOGRAPHY	ELONGATION
FILLET MACRO	GUIDED BEND (FACE)
FILLET BREAK	GUIDED BEND (ROOT)
ULTRASONIC	OTHER
OTHER	

We the undersigned certify that the data in this record are correct and that the test assembly was prepared, welded, and tested in accordance with the requirements of Section 4 of Appendix A of the Production Plan (TPP002-CDRL E002(A).

WELD ENGINEER ____________ DATE ______
QUALITY ASSURANCE ____________ DATE ______

CERTIFICATION

QUALIFIED FOR:

☐ FLAT ☐ VERTICAL (UP)
☐ HORIZONTAL ☐ OVERHEAD ☐ INCLINED

THICKNESS LIMITS ____________
QA ENGINEER ____________ DATE ______

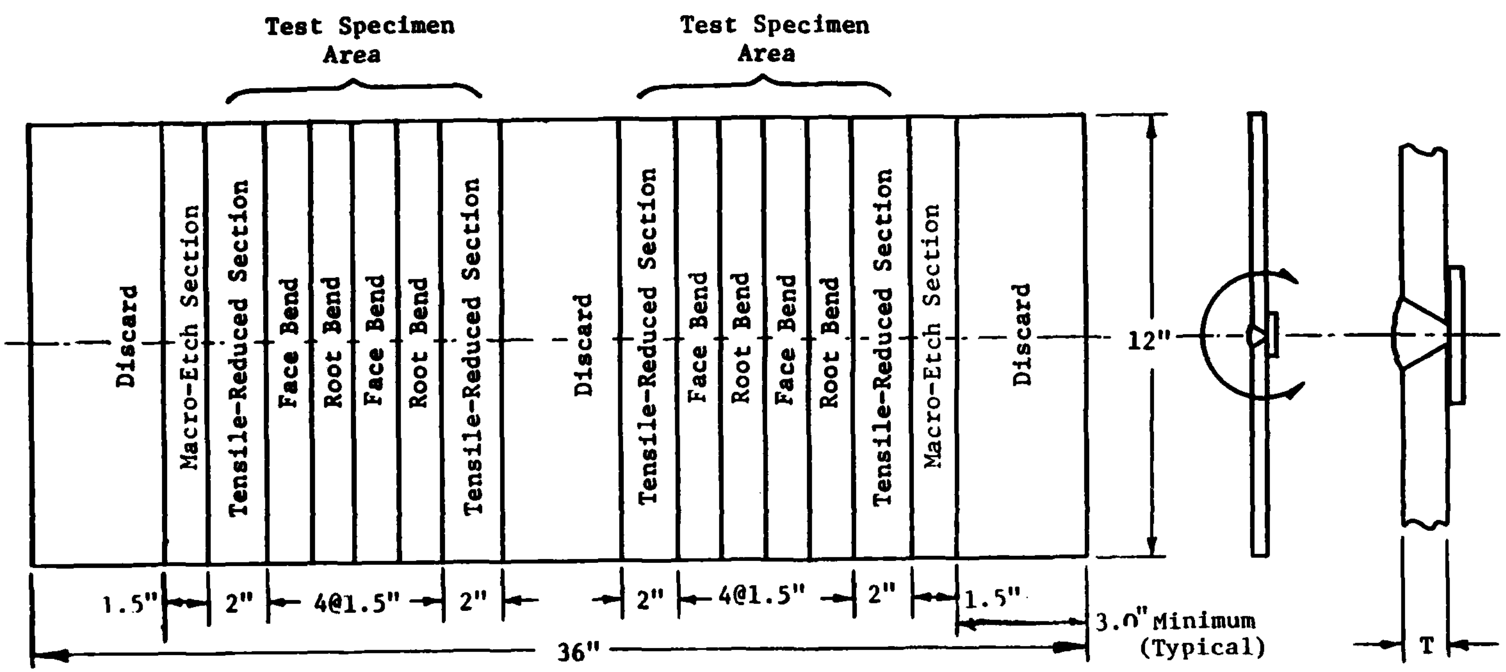
REMARKS:

GOVERNMENT APPROVAL

BY ____________ DATE ______
NAME ____________
TITLE ____________

FORM QA 12-R4 8/7/79

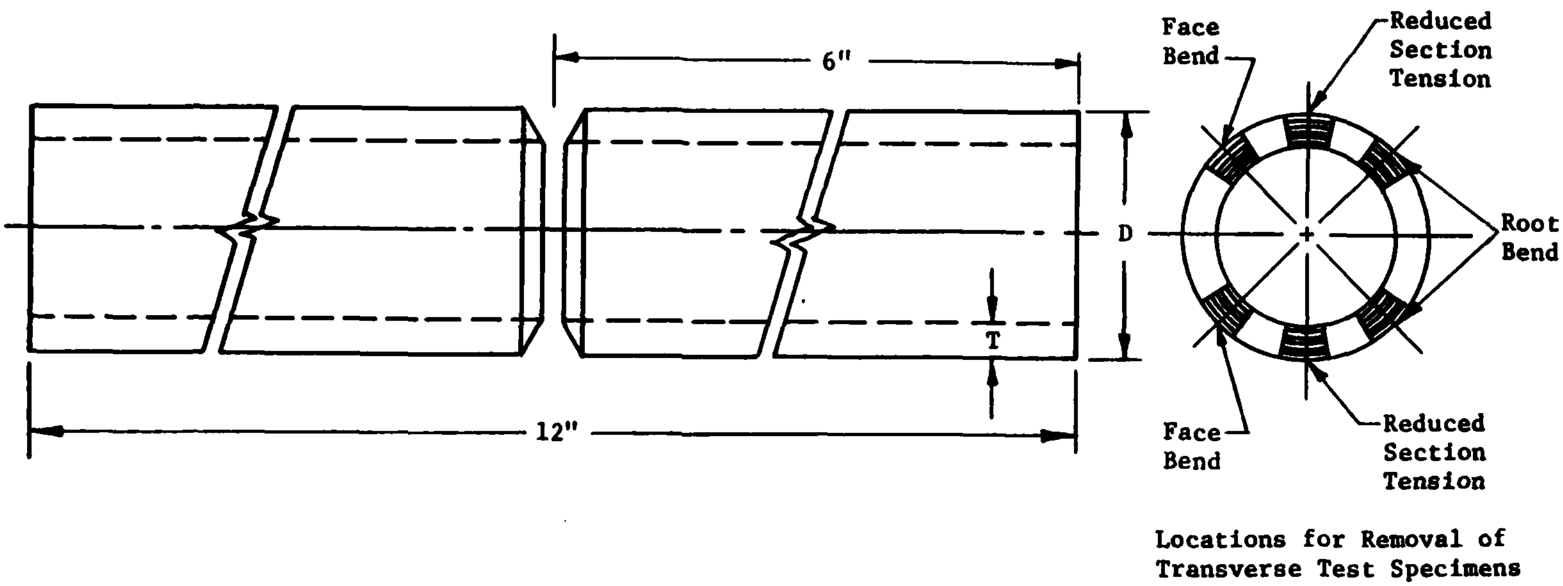
Figure 4-2. Typical Example of a Welding Procedure Qualification Data and Test Report



Notes: 1. Test assemblies made using semiautomatic equipment may include one test specimen area, as illustrated, and will not be less than 18 inches in length.

2. Material thickness, joint design and type of backing to be as specified in the weld procedure.

Figure 4-3. Butt Welding Procedure Qualification Test Assembly for Plates, Shapes, Castings and Forgings.



Note: Material thickness, diameter, and joint design to be as specified in the weld procedure.

Figure 4-4. Butt Welding Procedure Qualification Test Assembly for Pipe and Tubing.

4.3.4.1.3 Test Assembly Joint Design (4.4.1.3) -- Each test assembly will employ a butt joint design from the detail 3KSES hull structure design drawings. Separate procedures and test assemblies will be prepared for each variation of butt joint design, e.g., square groove, bevel, J groove, etc.

4.3.4.1.4 Preplaced Filler Metal Insert Joints (4.4.1.4) -- Preplaced filler metal insert joints, if used in the 3KSES hull structure, will comply with MIL-STD-248C.

4.3.4.1.5 Material Thickness Qualification Limits (4.4.1.5) -- Test assemblies of the thicknesses shown below will be prepared. Qualification of the test assemblies qualifies procedures for the thickness ranges shown in Table 4-3.

Table 4-3. Welding Procedure Qualification Material Thickness Limits

Test Assembly Nominal Thickness (inches)	Thickness Range Qualified (inches)
Plates, Shapes, Forgings, Castings	
Welds Made From One Side (One Pass)	
.190	.160*-.250
Welds Made From Two Sides	
.500	.160 - .750
1.000	.751 - 1.500
2.000	1.501 and up
Tubing	
.250	.058 - .500
.625	.501 and up

* Thickness of thinnest plating in hull structure.

4.3.4.1.6 Joint Design Qualification Limits (4.4.1.7) -- Each type of joint design, except fillet weld joints, specified on the 3KSES hull structural drawings will be qualified by a separate procedure for each thickness range of Table 4-3 as applicable; fillet weld procedures will be qualified as specified in paragraph 4.3.4.3 below.

4.3.4.1.7 Evaluation of Procedure Qualification Test Results (4.4.1.8) -- Test results will be evaluated in accordance with paragraph 4.3.5 below.

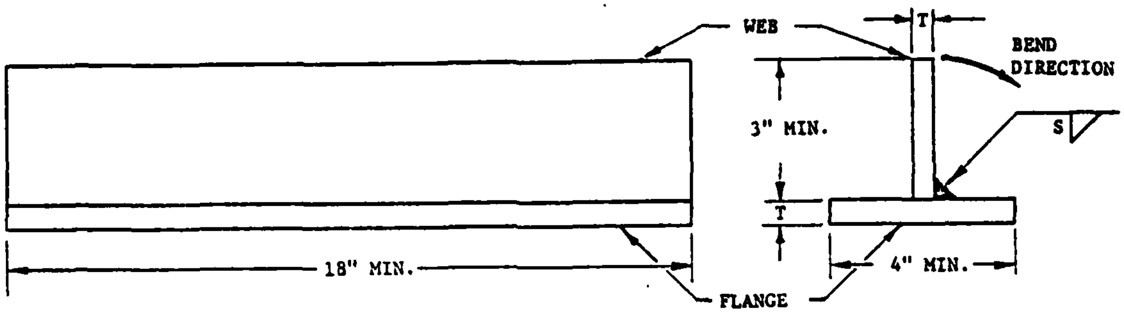
4.3.4.1.8 Use of Qualified Weld Procedures for Repair, Build-Up and Shrink Welds -- Groove weld procedure qualifications will constitute approval for repair and buttering (build-up) with deposited metal depth limited to the thickness limitations of the procedure. Qualified groove weld procedures will be approved for producing shrink welds subject to the limitations in Section 13 of this document.

4.3.4.2 Dissimilar Metal Welds (4.4.3) -- All combinations of base materials and filler material specified for use in the 3KSES hull structure are compatible for welding and are not considered to be dissimilar metal welds.

4.3.4.3 Fillet Welds (4.4.4)

4.3.4.3.1 Base Material (4.4.1.1) -- Qualification test assemblies will be made using base materials as specified in paragraph 4.3.4.1.1 above.

4.3.4.3.2 Fillet Weld Qualification Requirements (4.4.4.1) -- Procedures for depositing fillet welds on bare surfaces (except for structural tubing applications with requirements as specified in paragraph 4.3.4.5 below) will be qualified using the assembly illustrated in Figure 4-5. The test assembly will be welded with type 5556 aluminum alloy electrode and the qualification



Notes: 1. Material thickness, fillet size, and qualification limits will be as follows:

Thickness	Fillet Size	Fillet Size Qualification Limits
5/16	1/4	1/8 - 3/8
1/2	5/8	7/16 - 3/4

2. Positions are qualified as specified in Table 4-1.

3. Destructive bend test(s) of the full length of weld, less 1 1/2 inches maximum discard on each end, will be performed by bending the web in the direction indicated until weld fracture or web is bent flat, whichever occurs first.

4. Test assembly may be cut to shorter lengths after welding to facilitate testing.

Figure 4-5. Test Assembly for Qualification of Fillet and Lap Weld Procedures.

limits will be in accordance with Figure 4-5. Qualified fillet weld procedures made with aluminum alloy Type 5456 base metal/5556 filler metal combinations are considered qualified for welding Type 5454 or 5083 base metals with Type 5556 electrode. Fillet weld test assemblies will meet the Class I visual inspection requirements of Section 8 and the contour requirements of Section 14 prior to performing the tests described in paragraphs 4.3.4.3.3 and 4.3.4.3.4 below.

4.3.4.3.3 Macro-etch Test -- Macro-etch specimens from the fillet weld test assembly will be prepared and examined as specified in paragraph 4.3.5.2.6. Specimens which fail to meet the requirements of paragraph 4.3.5.2.6 are not acceptable.

4.3.4.3.4 Fillet Weld Break Test -- For procedure qualification the test assembly will be bent until flattened in accordance with Figure 4-5 such that the root of the weld is in tension. The test fails if visual examination of the weld fracture surface reveals one or more of the following conditions:

a. Evidence of any cracks.
b. Any incomplete root fusion indications which exceed 1/4 inch in length.
c. More than two incomplete root fusion indications,each not larger than 1/4 inch and separated by 1/4 inch (or less) in any six inches of weld.
d. Any porosity or "wormhole" indication larger than 3/32 inch.
e. More than 5 pores larger than 1/16 inch in any 1 inch of weld.

The test is acceptable if the test assembly bends without fracture.

4.3.4.3.5 Welding Over Primer Coated Surfaces (4.4.4.2) -- Welding will not be performed over primer coated surfaces of the hull structure.

4.3.4.4 Welds Made Without Adding Filler Metal (4.4.7) -- Welds made without adding filler material are not anticipated for use in the 3KSES hull structure.

4.3.4.5 Seal and Pipe Socket Welds (4.4.8) -- Seal welds will be qualified by preparation of a test assembly which simulates the joint

design and uses identical base materials and thicknesses and contains at least 15 inches of seal weld. It will be macro-examined as specified below in paragraph 4.3.5.2.6. Socket welds and edge seal welds may also be qualified by performing standard groove (butt) weld qualification.

4.3.4.6 Stud Welding

4.3.4.6.1 Procedure Requirements (4.4.6.2) -- Each stud welding procedure for qualification will contain, as a minimum, the following essential elements:

a. Equipment used.

b. Stud material and size.

c. Base material and thickness.

d. Gas shield and flow.

e. Timer range setting.

f. Maximum cable length.

g. Amperage range.

h. Direct current (dc) and polarity, or alternating current (ac).

i. Results of bending or torque testing.

4.3.4.6.2 Written Procedure Content (4.4.6) -- Stud welding procedure qualification records will contain, as a minimum, the pplicable requirements listed in 4.3.4.6.1 above.

4.3.4.6.3 Method of Qualification (4.4.6.1) -- A minimum of 10 studs (see MIL-S-24149 and MIL-S-24149/2) will be welded for each material combination and will include the minimum and maximum diameter studs to be used in production. The studs will be inspected and tested as follows:

a) The joint will comply with the visual inspection requirements of paragraph 8.4.1.14 of this document.

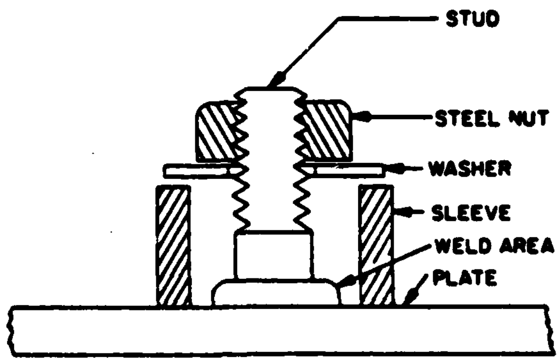
b) For aluminum (5000 series) studs; each stud will be bent to an angle of 15 degrees with no visible evidence of cracking in the weld zone or shank. The device used for bending should be similar to that shown on Figure 4-6B.

c) As an alternate to the bend tests, the studs may be torque tension tested to the maximum load listed in Figure 4-6. Any convenient means may be employed for applying torque tension such as use of a sleeve, nut, and washer (or suitable bolt for internal threaded studs) as shown on Figure 4-6A plus a torque wrench.

4.3.4.7 Other Welds -- Other weld joints, as defined in paragraph 11.4.5 of this document, will be qualified in accordance with paragraph 4.3.4.1.

4.3.4.8 Weld Repair Procedures -- Written procedures which include, as a minimum, the technique for locating and excavating the defect and the applicable weld procedure will be prepared for repair of defective welds. The effectiveness of these procedures will be demonstrated in the Structural Test Program and the Weld Development Program and preproduction efforts, or by special development prior to use on production repairs. GMAW procedures which are qualified in accordance with paragraph 4.3.4 of this document may be used for weld repair without additional qualification. GTAW procedures which are qualified per paragraphs 4.3.3 and 4.3.4 of this document may be used for repairs of small local defects, areas where access is limited or areas where high residual stress is present. The repair procedures will be approved by the Contractor's Material Review Board (MRB) and the Government Representative. An example of a repair procedure is presented in Figure 4-7.

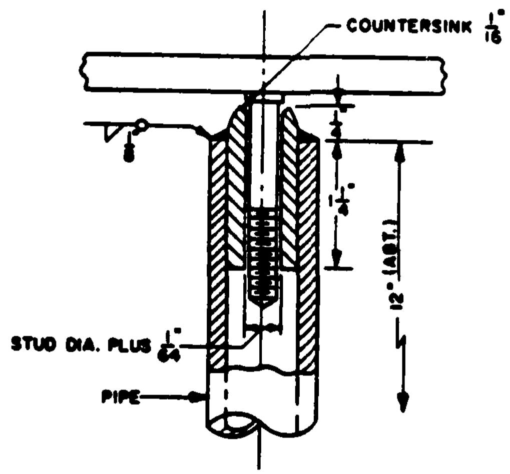
4.3.5 EVALUATION OF PROCEDURE QUALIFICATION WELDMENTS (4.5) -- This section provides methods for evaluation of the tests required for the qualification of welding procedures. The type and number of



Minimum Failure Load
(5000 Series Al. Alloy Studs)

Stud Size	Torque (IN-LB)
1/4 - 20	60
5/16 - 18	115
3/8 - 16	195
7/16 - 14	290
1/2 - 13	435

A. Stud torque testing apparatus and requirements.



B. Device for bending welded studs.

Figure 4-6. Stud Testing Apparatus (From MIL-STD-248C).

3KSES STANDARD REPAIR PROCEDURE 56-2.6-XX

APPLICATION — This procedure is applicable when authorized for disposition of a non-conformance in accordance with the Quality Program Plan. This procedure may be used for correction of a specific internal weld defect (or defects) such as porosity, slag, inclusions, lack of fusion or lack of penetration which exceed acceptance standards and require repair.

CAUTION — This procedure is limited to a maximum of two attempts to correct any identified non-conformance. If two attempts to correct the defect(s) are unsuccessful, a Material Review Request will be prepared and presented to the Material Review Board.

PROCEDURE

1. Identify location of defect accurately on weld marking off six inches on each side of defect(s).
2. Remove the weld between marked off area to approximately 1/2 weld thickness using a rotary file or gouge.
3. Inspect informally using radiography to ensure that all defective area is removed.
4. If there are remaining indications, continue filing or gouging as necessary for complete removel.
5. Clean affected area using M103 solvent and stainless steel wire brush.
6. Allow dampened area to thoroughly dry.
7. Reweld using an approved weld procedure designated by the Welding Engineer; use start and stop tabs as required.
8. Inspect by radiography covering the length of repaired weld and at least 6 inches of unrepaired weld at each end of the repair. The acceptance class specified in paragraph 8.3 of RMI Report TPP002 CDRL E00K(A)) is applicable.
9. If new defect(s) are identified, treat as a new non-conformance(s) and initiate appropriate repair action.

Approved:____________________ MRB Chairman

Approved:____________________ Government Representative

Figure 4-7. Sample of a Standard Repair Procedure.

destructive and type of non-destructive tests required of each assembly will be as defined in Table 4-4.

4.3.5.1 Non-Destructive Tests (4.5.1) -- Prior to performing any destructive tests, the qualification test assembly will be subjected to the non-destructive tests.

4.3.5.1.1 Visual -- Visual examination will be performed to ensure suitability of the weld surface for performance of radiography and liquid penetrant tests. The weld surface is required to comply with the Class 1 acceptance standards specified in paragraph 8.4.2 of this document prior to preparation of the weld surface for radiographic or penetrant inspection.

4.3.5.1.2 Radiography, Liquid Penetrant and Ultrasonic (4.5.1.1) -- Radiographic and liquid penetrant inspection will be performed in accordance with Section 7 of this document. Ultrasonics may be used to supplement radiography and will be performed in accordance with Section 7 of this document when employed. Backing strips, if employed, will be removed (unless integral) and the weld surface prepared in accordance with paragraph 4.3.5.1.3 below prior to radiography.

4.3.5.1.3 Detailed Procedure -- Non-destructive test procedure will be as follows:

a. Subject the procedure qualification test assembly to visual examination. The weld reinforcement surfaces and profiles must conform to the visual acceptance requirements of paragraph 4.3.5.1.1 above.

b. Apply liquid penetrant per Section 7 of this document and examine for cracks and surface imperfections. The weld surface will comply with the Class 3 requirements of paragraph 8.5.4 of this document.

Table 4-4. Welding Procedure Qualification Assembly Test Requirements (Excerpted from MIL-STD-248C)

Material Type	Base Material Grouping Number	Destructive Testing 1		Non-Destructive Testing		
		Tensile 2	Face & Root Guided Bends 3	Radio-graph	Liquid Penetrant	Visual
Aluminum Alloy	S-22 4	2	2 ea.	X	X	X
	S-25 5	2	2 ea.	X	X	X

1 When required for the testing of specimens taken from thick test assemblies, the reduced section tensile specimens and side bend specimens will be cut into multiple specimens as permitted by MIL-STD-418.

2 Tensile tests will be conducted with transverse weld tensile specimens (round or reduced section).

3 When root and face bend tests are required and the qualification material thickness is 3/4 inch or greater, 3 side bends will be performed in lieu of face/root bends.

4 **S-22 grouping includes:**

a. **5454 extrusions per QQ-A-200/6.**

b. **5454 sheet and plate per QQ-A-250/10.**

5 **S-25 grouping includes:**

a. **5456 extrusions per QQ-A-200/7.**

b. **5456 sheet and plate per QQ-A-250/20.**

c. 5083 extrusions per QQ-A-200/4.

c. Smooth the weld reinforcements by removing surface discontinuities using suitable mechanical means. Smoothing will be done only to the extent necessary to remove surface irregularities which would serve to mask indications within the weld metal. This step may be omitted if visual inspection in Step "a" determines it to be unnecessary.

d. Make a radiograph per Section 7 of this document and examine for discontinuities such as porosity and sub-surface inclusions. Discontinuities in excess of the Class 1 requirements defined in paragraph 8.6.2 of this document will be cause for rejection. Procedure test assemblies which meet the Class 1 requirements will be destructively tested per paragraph 4.3.5.2 below.

4.3.5.2 Destructive Tests (4.5.2) -- All required specimen preparation, dimension and mechanical testing will be performed in accordance with MIL-STD-418. Weld reinforcements will be removed flush with the base material in preparing all tensile and bend test specimens.

4.3.5.2.1 Transverse Weld Tension Tests (4.5.2.1) -- For acceptance, transverse weld tension test specimens will have a tensile strength as follows:

Material	Specification	As-Welded Tensile Strength (ksi)
5456-H116 (Sheet & plate)	QQ-A-250/20	40
5456-H111 (Shapes)	QQ-A-200/7	40
5454-H32 (Sheet & plate)	QQ-A-250/10	31
5454-H111 (Shapes)	QQ-A-200/6	31
5083-H111 (Shapes)	QQ-A-200/4	39

4.3.5.2.2 All-Weld-Metal Tension Tests (4.5.2.2) -- All weld metal tension tests are required to meet the requirements of the filler material specification as follows:

Specification	Type	Minimum Tensile Strength
MIL-E-16053L	5556	42 ksi

4.3.5.2.3 Guided Bend Tests (4.5.2.3) -- Guided bend tests specified in Table 4-4 will be performed using face and root bend tests for base material less than 3/4 inch thick. Side bend tests will be employed for base material test assemblies in excess of 3/4 inch thickness.

For acceptance, the guided bend test specimen after bending will have no cracks or other open defects greater than 1/8 inch measured in any direction on the convex surface. Cracks occurring on the corners of the specimen during testing will not be considered unless there is definite evidence that they result from internal defects. Openings in the base metal outside the weld deposit and heat affected zone will not be cause for rejection.

4.3.5.2.4 Weld Metal Impact Test (4.5.2.4) -- Weld metal impact tests are not applicable to 3KSES procedure test assemblies.

4.3.5.2.5 Hardness Test (4.5.2.5) -- Hardness tests are not applicable to 3KSES procedure test assemblies.

4.3.5.2.6 Macro-etch Specimens (4.5.2.6) -- Specimens will be removed transverse to the weld, suitably prepared and etched to show weld cross-section and examined with 7.5X to 10X magnification. For groove, fillet, socket, and seal welds, discontinuities in the weld area greater than 1/32 inch or 10% of the thickness of the weld, whichever is less, will be unacceptable. Each cross-section will exhibit no cracks, except that linear or rounded discontinuities at the root of partial penetration welds (including welds with backing rings or straps that are not removed) are acceptable provided they do not exceed 1/32 inch in length and adjacent linear discontinuities are not closer than 1/8 inch.

4.3.6 DATA ACCUMULATION AND REPORTING FOR WELDING PROCEDURE QUALIFICATION (4.6) -- This section specifies the requirements for procedure qualification data reporting to obtain approval of a welding procedure test report.

4.3.6.1 Test Report (4.6.1) -- The procedure qualification test report will be prepared on a standard form similar in format to that presented in Figure 4-2. All data items relevant to the procedure being qualified will be recorded. Results of required destructive and non-destructive tests will be recorded and attested to by the stamp of the Quality Assurance engineer assigned responsibility for procedure certification. The completed form, signed by the certifying Quality Assurance engineer, will be submitted for government approval in accordance with paragraph 4.3.2.3 above.

4.3.6.2 Maintenace of Records (4.6.2) -- The approved procedure qualification reports and supporting radiographs will be maintained and dispositioned as specified in paragraph 5.6 of this document. The qualification test data raw records, destructive test specimens, and non-destructive test reports will be retained until written approval of the qualification test reports is received.

4.3.7 CHANGES REQUIRING LEVEL NO. I REQUALIFICATION OF PROCEDURE (4.7) -- New Welding Procedure Qualification and Test Data Sheets will be submitted to NAVSEA for approval when any of the changes in essential elements listed herein are made in the welding procedure. Changes, other than those listed in this paragraph and listed below in paragraph 4.3.8 for Level II qualification, may be made in a procedure without the necessity for requalification; however, the revised welding procedure with all changes identified will be submitted for information to the Government Representative. The changes specified below in paragraphs 4.3.7.1 through 4.3.7.8 require requalification of the welding procedure for qualification Level No. I.

4.3.7.1 Base Material (4.7.1) -- Change in base material from that indicated in the approved procedure will require requalification as follows:

a. Change from base materials indicated herein as authorized for 3KSES hull structure (Reference Table 10-1) to another material of a different S-group as given in Table I of MIL-STD-248C.

b. A change in base material thickness to a thickness outside the limits for which the procedure was qualified (Reference Table 4-3).

4.3.7.2 Filler Material (4.7.2) -- A change in filler material from type 5556 as specified in paragraph 10.2.2.1 to a filler material listed under a different A-number or not included in Table II of MIL-STD-248C will require requalification. A change from one filler material to another under the same A-number in Table II of MIL-STD-248C will not require requalification, but consideration must be made for any effect of the specific filler material on the joint strength.

4.3.7.3 Joint Design (4.7.3) -- The omission (or addition) of backing (strip, bar, tape, ceramic, etc.) on full penetration joints

welded from one side will require requalification. (Groove joints welded from both sides will be separately qualified.)

4.3.7.4 Process (4.7.4) -- A change in process from that indicated on the approved procedure will require requalification as follows:

a. A change from one welding process to another (gas metal-arc (GMAW) to gas tungsten-arc (GTAW)).

b. For the gas tungsten-arc process (GTAW), the addition (or omission) of filler metal.

c. A change within a process of arc-metal transfer characteristics (such as gas metal arc spray transfer to pulsed spray transfer).

d. A change in the method of welding among manual, semi-automatic, automatic and machine welding. (See definitions in Section 3 of this document.)

e. A change from single-arc to multiple-arc or vice-versa, or a change to another type of multiple-arc (e.g., from series to parallel arc).

4.3.7.5 Electrical Characteristics (4.7.5) -- A change in the welding current from alternating current (AC) to direct durrent (DC) or vice versa or a change from constant potential to constant current or vice versa requires that the procedure be requalified.

4.3.7.6 Position (4.7.6) -- A change in position from that in which the procedure is qualified (Reference Table 4-1) to any other position requires that the procedure be requalified.

4.3.7.7 Shielding Gas (Torch Gas) (4.7.7) -- Any change in the shielding gas parameters as indicated below from those for which the procedure was qualified requires requalification.

a. Change from an inert gas (helium, argon) to a mixture containing non-inert gases such as oxygen or vice versa.

b. Change from a single gas to a different gas or to a mixture of gases or vice versa.

c. A change of more than 10% in torch gas flow rate (by volume).

d. A change of more than 5% of any component gas (by volume) in a gas mixture.

4.3.7.8 Heat Treatment (4.7.8) -- A change in the preheat or interpass temperatures above or below the applicable ranges specified on the procedure will require requalification. (Post weld heat treatment is not permitted for 3KSES fabrication except when specified by the Material Review Board (MRB) with the concurrence of NAVSEA-PMS304 as a specific repair to reduce or eliminate distortion of nonconforming parts.)

4.3.8 PROCEDURE CHANGES REQUIRING LEVEL NO. II REQUALIFICATION (4.8) -- When any of the following changes are made to a procedure previously qualified to Level No. I, the procedure will be requalified per paragraph 4.3.2.6.2 of this document.

a. An increase in filler wire diameter of more than .015 inch for gas metal arc (GMAW), or more than 1/32 for gas tungsten arc (GTAW) over that previously qualified.

b. In automatic, machine and semi-automatic welding, a decrease of more than 20 percent in the included angle or root opening of the welding groove below that qualified.

c. A change of more than plus or minus 25 percent in the welding current or voltage from the range qualified.

d. A change in the type of backing for full penetration joints welded from one side.

4.4 WELDER PERFORMANCE QUALIFICATION

Performance qualification requirements for welders and welding operators will be as specified in MIL-STD-248 except as modified and amplified herein. Requirements from MIL-STD-248 are identified by the applicable

MIL-STD-248C paragraph number shown in parentheses following the paragraph titles in this section.

4.4.1 GENERAL REQUIREMENTS (5.2)

4.4.1.1 Responsibility (5.2.1) -- The Contractor will be responsible for establishing that each welder and welding operator who welds on the hull structure of the 3KSES has been qualified by demonstrating the ability to produce sound and satisfactory joints in accordance with the requirements of this section.

4.4.1.2 Prerequisite (5.2.2) -- Prior to performance qualification, the Contractor will have weld procedures which are qualified in accordance with Section 4.3. The welder will be made cognizant of the contents of the qualified procedure(s) and will demonstrate performance qualification in accordance with approved procedures and as specified in this section.

4.4.1.3 Method of Establishing Qualification (5.2.3) -- Welder and welding operator performance qualifications will be established as follows:

a. Each welder and welding operator will satisfactorily weld two applicable performance qualification test assemblies. Both test assemblies must pass test requirements or the test will be considered failed, and retest of two additional assemblies will be required.

b. Each qualification test assembly will be inspected in accordance with the requirements of this section.

c. The non-destructive and/or destructive tests will be evaluated in accordance with the applicable standards.

4.4.1.4 Alternate Qualifying Methods (5.2.4) -- Performance qualification may also be demonstrated by welding satisfactory procedure qualification test assemblies. Development of a welding procedure which

is approved per Section 4.3 of this document automatically qualifies the welder in that procedure and for the range of base material thicknesses covered by the procedure.

4.4.1.5 Qualification Limits by Base Material and Filler Metal (5.2.5) -- Welders and welding operators will be considered qualified only for the base materials and thicknesses specified in the approved procedure used for welding the performance qualification test assembly.

4.4.1.6 Qualification Limits by Position and Joint Type (5.2.6) -- Welders and welding operators will be considered qualified only for the positions and joint type qualified in the approved procedure used for welding the performance qualification test assembly.

4.4.1.7 Repair to Test Assemblies (5.2.8) -- Test assemblies which are made using semiautomatic or manual equipment may be repair welded under the following conditions:

a. No cracks, other than crater cracks, may be repair welded.

b. Only one cycle of repair welding is permitted.

c. The repair and all test results, including the NDT results which failed to meet the requirements, will be recorded on the permanent test record.

Qualification test assemblies for automatic and machine welding will not be repair welded.

4.4.1.8 Retests (5.2.9) -- If either of the two initial performance qualification test assemblies fails to meet applicable requirements, retests will be performed as follows:

a. One retest of two additional test assemblies may be made without further training for each initial test assembly that failed. Both of the retest test assemblies must pass the applicable requirements for qualification.

b. Subsequent retests may be allowed for each retest assembly that fails, provided that the welder or welding operator has had at least 8 hours of training or practice designed to correct the reasons for previous failures. Subsequent retests will consist of three test assemblies, all of which must pass acceptance requirements for performance qualification to be granted.

4.4.1.9 Transfer of Qualification (5.2.10) -- Transfer of qualification(s) of welders and welding operators may be made if the welder/welding operator is transferred from one activity to another - e.g., from the Contractor to one of its subsidiaries or vice-versa or from one work site to another.

4.4.1.10 Maintenance of Qualification (5.2.11) -- Qualification will be maintained by the performance of satisfactory production welding using the process(es) for which the welder/welding operator is qualified within each successive 3 month period after initial qualification.

4.4.1.11 Loss of Qualification (5.2.11.1) -- A welder/welding operator will lose performance qualification in any given procedure under the following conditions and will require requalification:

a. Failure to satisfactorily demonstrate production welding proficiency in the procedure during a three month period as defined above.

b. When the Government Representative, the Contractor's Quality Assurance certifying inspector, or the Contractor's Welding Engineer has specific reason to question the ability of the welder/welding operator to produce welds that meet the applicable requirements of this document.

4.4.1.12 Waiver of Qualification Tests (5.2.12) -- No waivers of qualification tests will be granted. Welders who have not qualified in a given weld procedure, or whose performance qualification has lapsed or been lost per paragraph 4.4.1.11 above, will not be permitted to weld on 3KSES hull structure using that procedure.

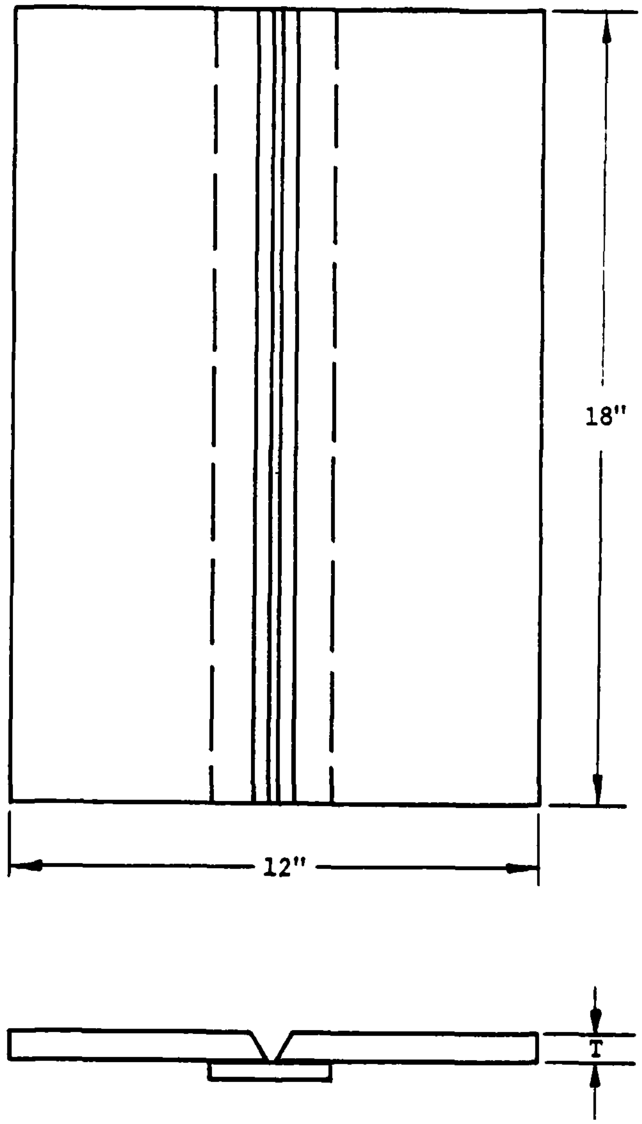
4.4.1.13 Vision Test Requirements (5.2.13) -- Each welder and welding operator will be required to pass an annual vision test. Vision tests will be conducted using standard test methods for determining visual acuity. The standard of acceptance will be natural or corrected near distance acuity such that the individual is capable of reading J1 letters on the standard Jaeger type chart for near vision.

4.4.2 WELDER AND WELDING OPERATOR PERFORMANCE QUALIFICATION TEST REQUIREMENTS (5.3)

4.4.2.1 Butt and Groove Joint Welder - Welder and welding operator performance qualification test requirements for Manual, Semi-Automatic, Automatic and Machine Welding processes are specified in the following paragraphs.

4.4.2.1.1 Base Material Form, Size and Thickness (5.3.1.1) -- Qualification tests performed on a given base material form and thickness will qualify the welder/welding operator performance to the same limits as the approved welding procedure with which the test assembly was fabricated (See Table 4-3). The qualification test assembly will be as shown in Figure 4-8 and will employ a butt joint identical to that shown in the approved procedure. Test assembly evaluation will be as specified below in paragraph 4.4.3.

4.4.2.1.2 Requirements for Repair Welding of Castings (5.3.1.2) -- Qualification in procedures approved for use with wrought aluminum as defined above in paragraph 4.4.2.1.1 will also qualify the welder for repair of castings.



NOTE: Material Thickness, Joint Design, and Type of Backing as specified in the Weld Procedure. The weld will include one stop and restart near the center of the test assembly to demonstrate crater fill technique.

Figure 4-8. Welding Performance Qualification Test Assembly for Plates, Shapes, Castings and Forgings.

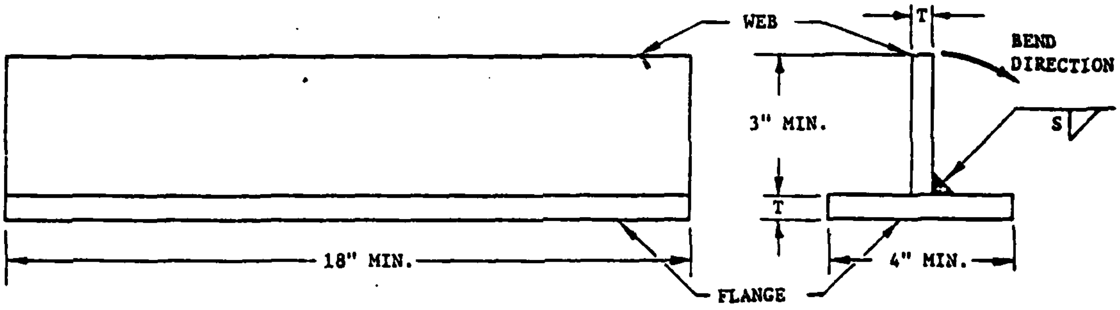
4.4.2.1.3 Automatic, Stud, and Machine Welding (5.3.1.3) -- Welding operators will qualify using equipment possessing control features similar to those of the equipment which will be used to make the production welds. The operator will be required to set up and adjust the equipment using the applicable parameters from a qualified welding procedure which will affect the welding characteristics and weld placement.

4.4.2.2 Tack and Fillet Welder (5.3.3)

4.4.2.2.1 Base Metal Form and Size (5.3.3.1) -- Performance qualification test for fillet/tack welders will consist of fabrication of at least one test assembly per Figure 4-9. The weld will be made using a qualified fillet weld procedure with the base material and filler wire specified in the procedure. The test assembly will be evaluated as specified in paragraph 4.4.3 of this document.

4.4.2.2.2 Extent of Qualification (5.3.3.2) -- Qualification will be limited to the fillet weld procedure, the positions as specified in Table 4-1, and the type of equipment used. Welding operators will be qualified for automatic fillet welds by successful demonstration of production welds.

4.4.2.3 Overlay Welding (5.3.4) -- Qualification in procedures approved for use with wrought aluminum as defined above in paragraph 4.4.2.1.1 will also qualify the welder/welding operator for overlay welding used for buttering or build-up.



1. Material thickness(T) and fillet size(S) will be as specified in the weld procedure.
2. Positions are qualified as specified in Table 4-1.
3. Test assemblies will include at least one stop and restart near the center of the test assembly to demonstrate crater fill technique. For multiple pass joints the arc will be stopped and restarted in the first pass.
4. Destructive bend test(s) of the full length of weld (less 1 1/2 inch maximum discard at each end) will be performed by bending the web in the direction indicated until weld fracture or the web is bent flat, whichever occurs first.
5. The test assembly may be cut to shorter lengths to facilitate testing.

Figure 4-9. Fillet Weld and Lap Weld Test Assembly for Welder and Welding Operator Performance Qualification.

4.4.2.4 Seal Welder (5.3.5) -- Performance qualification of seal welders will consist of preparation of a procedure qualification test assembly as specified in paragraph 4.3.4.5 of this document. Acceptance criteria will be as defined in paragraph 4.3.5.2.6.

4.4.2.5 Stud Welder -- Performance qualification of stud welders will consist of successful demonstration of stud welds as specified in paragraph 4.3.4.6.3 of this document.

4.4.3 TEST AND EVALUATION OF QUALIFICATION TEST ASSEMBLIES (5.4) -- This section describes the methods and acceptance standards to be used in the evaluation of performance qualification test assemblies. Plate and pipe butt weld performance qualification test assemblies will be subjected to visual and radiographic inspection only; guided bend tests and tensile tests are not required. Tack and fillet weld performance qualification test assemblies will be subject to visual and weld break tests only. Stud weld performance qualification test assemblies will be subject to the requirements of paragraph 4.3.4.6.3 above.

4.4.3.1 Non-Destructive Inspection (5.4.1)

4.4.3.1.1 Visual Examination (5.4.1.1) -- Visual examination will be made of all performance qualification test assemblies for weld surface geometry and weld surface soundness. Except for stud welds, the assembly will conform to the visual requirements of paragraph 4.3.5.1.1 of this document. For stud welds, the assembly will conform to the visual requirements of paragraph 4.3.4.6.3 of this document.

4.4.3.1.2 Radiographic Inspection (5.4.1.2, 5.4.1.3) — Radiographic inspection will be performed in accordance with Section 7 of this document. Acceptance standards for radiography will be in accordance with paragraph 8.6 of this document. Inspection class requirements will be as defined below in paragraph 4.4.3.1.3.

4.4.3.1.3 Non-Destructive Test Procedure -- Non-destructive test procedures for plate and pipe butt weld performance qualification test assemblies will be as follows:

a. Subject the performance qualification test assembly to visual examination per paragraph 4.4.3.1.1 above.

b. Apply liquid penetrant, Group 3 per MIL-STD-271, and examine for cracks and surface imperfections. Discontinuities in excess of the Class 3 requirements as defined in paragraph 8.5.4 of this document will be cause for rejection.

c. If required, smooth the weld reinforcement (both sides) by removing surface discontinuities by suitable mechanical means. The reinforcements will be dressed only to the extent necessary to remove surface discontinuities which would tend to mask internal indications. Weld reinforcement profile will be faired into the base material.

d. Make a radiograph per MIL-STD-271 and examine for discontinuities such as porosity and other subsurface inclusions. If indications are within the limits of Class 1 as defined in paragraph 8.6.2 of this document, the test assembly will be considered acceptable and the welder qualified. Discontinuities in excess of the Class 3 requirements of paragraph 8.6.4 of

this document will be cause for rejection. Indications within the limits of Class 3 are acceptable, but examination must be continued through the below listed steps.

e. If the indications in step d are within Class 3 or Class 2, but not Class 1, the weld reinforcements on both sides of the test assembly will be ground flush and the weld re-radiographed. The weld must be within the limits of Class 1 to be acceptable and the welder/welding operator qualified.

4.4.3.2 Destructive Tests (5.4.2) -- Destructive tests will be performed to qualify fillet and tack welders and seal welders. All required specimen preparation and dimensions will be in accordance with the requirements of Figure 4-9.

4.4.3.2.1 Fillet Weld (5.4.2.2) -- For tack and fillet welder qualification (except for piping applications), the test assembly web will be bent over until flattened in accordance with Figure 4-9 such that the root of the weld is in tension. The test fails if one or more of the following conditions is present:

a. There is evidence of any cracks.

b. There is incomplete root fusion in excess of 10% of the weld length.

c. There is evidence of the following types of porosity:

   1. Any pores larger than 3/32 inch diameter and there are either more than 3 pores per inch of weld or more than 10 pores per 8 inches.
   2. No pores larger than 3/32 inch diameter and there are more than 5 pores per inch of weld.

   Pores must be larger than 1/16 inch diameter to be counted in c.1 and c.2 above.

The test is acceptable if the test assembly bends without fracture.

4.4.3.2.2 Macro-etch Specimens (5.4.2.3) -- (Limited to seal welds.) Specimens will be extracted transverse to the weld, prepared and etched to show weld cross section and examined at 7.5X to 10X magnification. Acceptance standards will be as defined in paragraph 4.3.5.2.6 of this document.

4.4.4 DATA ACCUMULATION AND RECORDS (5.5) -- This section provides requirements for performance qualification data accumulation and maintenance of records. The required format will be similar to that shown in Figure 4-10.

4.4.4.1 Records (5.5.1) -- The welder qualification test record will contain the following information:

a. Welder or welding operator identification (name, employee number).

b. Date of test.

c. Qualification test number.

d. Procedure number (identifies procedure to which qualified -- includes process, equipment, base and filler material, position and electrical characteristics).

e. Type of inspection(s) performed.

f. Results.

g. Certifying signature by authorized Quality Assurance inspector.

4.4.4.2 Performance Qualification Summary -- A performance qualification summary which lists all procedures for which each welder is qualified will be maintained.

WELDER/WELDING OPERATOR PERFORMANCE QUALIFICATION TEST RECORD	DATE OF TEST:_____
Welder/Welding Operator: Name_____	Employee No.:_____ Welder No.:_____
Performance Qualification Ident. No.:_____	Procedure No.:_____ Design: Butt/Fillet/Seal/Stud
Test Assembly: Plate_____ Pipe_____ Stud_____	Base Material: AL ALY 5456, QQ-A-200/7 QQ-A-250/20 AL ALY 5454, QQ-A-200/6 QQ-A-250/10 AL ALY 5083, QQ-A-200/4
Position: Flat Horizontal Vertical (Up) Overhead	Filler Material: Type 5556, Diameter:_____
Manual (GTAW only) Semi-Automatic Machine - (Wiggler/Pacer) Automatic	GMAW GTAW Spray Transfer

Date of test assembly examination:_____

Qualification test results: Qualified_____
Not Qualified_____

Certification of Examiner:_____

Examination Results	Pass/Fail	Inspector
Visual - All		
Radiography - Butts and Grooves only		
Break Test - Tack and Fillet only		
Macro-etch - Seal Weld only		
Bend/Torque Tension - Studs only		

Figure 4-10. Sample Format of Welder/Welding Operator Performance Qualification Test Record

4.4.5 CHANGES REQUIRING REQUALIFICATION OF WELDER/WELDING OPERATOR (5.6) -- Each welder/welding operator is required to be qualified in each welding procedure that the welder/welding operator utilizes in production work. Any change in a welding procedure parameter which requires Level I requalification as specified in paragraph 4.3.7 of this document also requires welder/welding operator performance requalification using the requalified procedure.

4.5 NON-DESTRUCTIVE TEST (NDT) PERSONNEL QUALIFICATION

Personnel performing visual, liquid penetrant, radiographic, and ultrasonic inspection will be qualified in accordance with Reference Document SNT-TC-1A as specified herein.

4.5.1 SCOPE -- This section contains the requirements for qualification of non-destructive test personnel who will be assigned inspection responsibilities for the 3KSES hull structure. Qualification requirements are provided for the following categories of inspection.

a. Visual

b. Liquid Penetrant

c. Radiography

d. Ultrasonics

4.5.2 RESPONSIBILITY -- The Contractor will certify that non-destructive test personnel assigned to inspect the 3KSES hull structure are qualified to the requirements of this section. Records of vision examination and performance qualification training and examinations will be maintained and made available to the Government Representative.

4.5.3 NON-DESTRUCTIVE TEST PERSONNEL CLASSIFICATION BY METHOD AND LEVEL -- The methods and levels contained in Document SNT-TC-1A will be utilized as shown in Table 4-5. The additional method of

"visual inspection" will also be employed to designate those inspectors qualified to inspect and accept/reject materials to the requirements of Section 8 herein.

Table 4-5. Non-destructive Test Methods and Levels of Qualification.

	Visual (VT)	Liquid Penetrant (PT)	Radiography (RT)	Ultrasonic (UT)
Level I	--	X	X	X
Level II	X	X	X	X
Level III	X	X	X	X

4.5.3.1 Methods of Inspection -- Proficiency of an inspector in the given NDT method will be demonstrated and certified prior to assignment of that inspector to inspection duties using that method. An inspector will separately qualify for each method defined below but may receive qualification in any method or combination of methods.

4.5.3.1.1 Visual Inspection (VT) -- Visual inspection is the examination of fabricated hull structure or test assemblies, including welds, for compliance with the visual requirements of paragraph 8.4 herein. Visual inspection also includes the examination for fitup, fairness and distortion in accordance with the requirements of Chapter 12 of this document.

4.5.3.1.2 Radiographic Inspection (RT) -- Radiographic inspection is the examination of welded structure or test assemblies with radiography (X-rays) using methods specified in Section 7 herein and interpretation of the radiographs in accordance with the standards given in paragraph 8.6 herein.

4.5.3.1.3 Liquid Penetrant Inspection (PT) -- Liquid penetrant inspection is the examination of welded structure or test assemblies using penetrants conforming to MIL-I-25135 in accordance with the methods specified in Section 7 herein and the interpretation of indications in accordance with the standards given in paragraph 8.5 of this document.

4.5.3.1.4 Ultrasonic Inspection (UT) -- Ultrasonic inspection is the examination of welded hull structure using ultrasonic methods as specified in Section 7 herein and the interpretation of indications in accordance with the standards of paragraph 8.7 of this document.

4.5.3.2 Levels of Qualification -- There are three basic levels of qualification applicable to NDT inspectors. Qualification Level I is the lowest or initial qualification, and Level III is the highest and most comprehensive classification.

4.5.3.2.1 Trainee -- An individual in the process of being qualified for certification to NDT Level I will be considered a trainee. A trainee will work only with a certified inspector and will not independently conduct, test nor interpret or report the results of any inspection (test).

4.5.3.2.2 NDT Level I -- An inspector certified as NDT Level I will be qualified to properly perform specific calibrations, specific tests, and specific evaluations according to written instructions and to record the results. A Level I inspector will receive the necessary guidance or supervision from a certified NDT Level II or III inspector.

4.5.3.2.3 NDT Level II -- An inspector certified as NDT Level II will be qualified to set up and calibrate equipment and to interpret and evaluate results with respect to applicable codes, standards, and specifications. A Level II inspector will be thoroughly familiar with

the scope and limitations of the method and will exercise assigned responsibility for on-the-job training and guidance of trainee and NDT Level I personnel. The Level II inspector will be able to prepare written instructions, and to organize and report non-destructive testing investigations.

4.5.3.2.4 NDT Level III — An inspector certified as NDT Level III will be capable of and responsible for establishing techniques; interpreting codes, standards and specifications; and designating the particular test method and technique to be used. The Level III inspector will be responsible for the complete NDT operation in which he or she is qualified and assigned, and will be capable of evaluating results in terms of existing codes, standards, and specifications. The Level III inspector will have sufficient practical background in applicable materials, fabrication, and/or product technology to establish techniques and to assist the design engineer in establishing acceptance criteria where none is otherwise available. It is desirable that the Level III inspector has general familiarity with all commonly used NDT methods. The Level III inspector will be responsible for the training and examination of NDT Level I and Level II personnel for certification. (The actual administration of training and grading of examinations may be delegated to a Level II individual and so recorded.)

4.5.3.3 Education, Training and Experience Requirements for NDT Personnel -- Candidates for certification in non-destructive testing will have sufficient education, training and experience to ensure understanding of the principles and procedures of those areas of testing in which they are being considered for certification.

Prior to certification, a candidate will satisfy the training and experience requirements defined below for the applicable NDT level. Documented training and/or experience gained in positions and activities equivalent to those of Level II or III prior to establishment of this

document will be considered as satisfying the criteria of paragraphs 4.5.3.3.1 and 4.5.3.3.2 for certification.

4.5.3.3.1 NDT Levels I and II -- Minimum training and experience requirements for qualification to Level I and II will be as defined below in Table 4-6. The experience factor in months will be based on a 40 hour work week. When applicable work is performed in excess of 40 hours per week, credit may be based on actual hours. Records will be kept in terms of hours.

Table 4-6. Minimum Requirements for NDT Inspector Training and Experience

	Visual (VT)	Radiography (RT)	Ultrasonic (UT)	Penetrant (PT)
		Training Hours		
Level I	4	20	40	4
Level II	8	40	40	8
		Work Time Experience (Months)		
Level I	1	3	3	1
Level II	2	9	9	2

NOTES 1. The training will be as described below in paragraph 4.5.4.

2. The above requirements are based on education equivalent to high school graduation.

4.5.3.3.2 NDT Level III -- Level III Visual Inspectors will be selected and designated from personnel who have work experience of 24 months or more as a Level II Visual Inspector (or equivalent). Level III Liquid Penetrant Inspectors will be selected and designated from personnel who have work experience of 24 months or more as a Level II Liquid Penetrant Inspector (or equivalent). Level III Radiographers

will be selected from personnel with 24 months, or more, work experience as a Level II Radiographer (or equivalent). Designation of a Level III Radiographer will be contingent on satisfactory completion of an examination administered by the American Society of Non-Destructive Test (ASNT) and designation as an ASNT Level III Radiography Examiner.

4.5.4 TRAINING PROGRAM -- The Contractor will conduct a training program to implement the requirements for certification training of NDT personnel leading to certification. The training program will be conducted by a certified Level III Test Examiner and will be based on the requirements of SNT-TC-1A.

4.5.5 EXAMINATIONS -- Candidates for certification as Level I or Level II NDT inspectors in visual, liquid penetrant, radiography, and ultrasonic methods will, upon completion of required training and work experience, be subjected to the following examinations.

4.5.5.1 Vision Examination -- All non-destructive test personnel (including trainees) will be required to pass the vision test as specified in SNT-TC-1A for NDT personnel. Up to and including age 35, the vision test will be taken annually; above 35, semi-annually.

4.5.5.2 Written Examination -- Candidates for Level I and II inspectors will successfully undergo a written examination conducted by an individual certified as a Level III Examiner. This examination will include a general section covering basic test principles relative to the applicable method, and a specific section covering equipment operating procedures and test techniques that the applicant may encounter in his duty assignment.

4.5.5.3 Practical Examination -- Each candidate for Level I or II inspector will demonstrate to the satisfaction of a Level III Test Examiner that he is familiar with and can operate the necessary test equipment and can analyze the resultant information to the degree required.

The candidate will successfully test at least one specimen and analyze the results of the test to the satisfaction of the Test Examiner.

4.5.6 CERTIFICATION -- Candidates for Level I and Level II inspectors who successfully complete the work experience, training, and examination requirements will be certified in the appropriate method by a Level III Examiner. Records of work experience, training, examination results and certifications will be maintained for each NDT inspector. Multiple certifications may be in force concurrently for a given inspector.

4.5.6.1 Notification of Certification -- A written notification of all personnel qualified for NDT inspection functions and the levels and methods for which certified will be provided to the Government Representative prior to start of production. Notification of any changes thereto will be provided to the Government Representative as they occur.

4.5.7 REQUALIFICATION -- NDT personnel will be requalified as required below by undergoing vision, written, and practical examinations. On successful completion of such examinations, the inspectors will be recertified. Requalification is required:

a. At three year intervals from the date of initial qualification.

b. If personnel are not actively engaged in the NDT method for which qualified for a six month period.

c. Whenever, in the opinion of a Level III Examiner, the individual is unable to perform competently in the method and at the level for which certified.

4.6 NON-DESTRUCTIVE TEST PROCEDURE QUALIFICATION

4.6.1 LIQUID PENETRANT PROCEDURE QUALIFICATION -- Liquid penetrant inspection procedures will be qualified prior to use for evaluating test assemblies or production welds on the 3KSES hull structure. For procedure qualification, the Contractor will prepare a written procedure

which has proven ability to detect the smallest rejectable surface defects in a test specimen, whether these defects are natural or artificially produced. The Contractor will certify that the procedure is in accordance with MIL-STD-271 and will, upon request by the Government Inspector, make the procedure available and demonstrate its validity by performing inspection on the test specimen.

The written procedure will include at least the following information:

a. Brand name and specific group type per MIL-STD-271, number and letter designation, or both, of penetrant, emulsifier, penetrant remover and developer.

b. Details of the method of precleaning and drying, including cleaning materials used and time allowed for drying.

c. Details of the method of penetrant application, the length of time that the penetrant remains on the surface, and the temperature of the surface during penetration.

d. Details of the method of removing excess penetrant from the surface, and of drying the surface before applying the developer.

e. Details of the method of applying the developer and the length of developing time before inspection.

f. Method of post-test cleaning.

g. The applicable acceptance standards.

When the brand or type of penetrant, penetrant remover (solvent) or developer differs from that specified in the procedure, a new procedure will be prepared which includes all the above information.

4.6.2 RADIOGRAPHIC PROCEDURE QUALIFICATION -- Radiographic procedures, including film processing techniques, will be qualified prior to use for evaluation of test assemblies or production welds of the 3KSES hull structure. Radiographic procedure qualification may be authorized separately from film processing procedure qualification provided that a qualified film processing facility is utilized.

4.6.2.1 Procedure for Obtaining Qualification -- Before any radiography is performed, the Contractor will:

a. Apply, in writing, for standard radiographic procedure qualification plates through the local Defense Contract Administration Service Quality Assurance Representative (DCAS/QAR) to the Commander, Norfolk Naval Shipyard (Industrial Laboratory Division), Portsmouth, VA 23704. The submitted application will include the following information:

   (1) The type of base material to be qualified.

   (2) The radiation sources to be qualified (e.g., X-ray machine voltage ratings and manufacturer).

   (3) The material thickness ranges to be qualified.

   (4) The name of the qualified organization that will process the film and identification of the film processing procedures.

   The Norfolk Navy Shipyard will respond to the application and will provide the necessary test plates together with instructions for their use and standard data sheet blanks.

b. Radiograph the standard test plates in accordance with the instructions accompanying the test plates and MIL-STD-271.

c. All variables of the proposed radiographic procedure used to radiograph the standard test plates will be recorded.

d. Obtain approval of the procedure by submitting radiographs in duplicate of each standard test plate and the record of the essential elements of the test procedure through DCAS/QAR to the Commander, Norfolk Naval Shipyard (Industrial Laboratory Division).

4.6.2.2 Standard Qualification Test Plates -- The standard qualification test plates supplied by the Norfolk Navy Shipyard contain

synthetic defects of known size and location. Standard test plates for the qualification of aluminum alloy radiographic procedures will be as defined in Table 4-7.

Table 4-7. Standard Radiographic Qualification Test Plates For Aluminum

Test Plate Thickness (Inches)	Qualification Thickness Range (Inches)
*	Below 1/4
3/8	1/4 - 3/4
1	3/4 - 1-1/2
2	1-1/2 - 4
4	4 - 6

* The Contractor will submit radiographs of the thinnest plate or sheet to be used in production of 3KSES hull structure. Additional plates to be submitted will include 3/8, 1 and 2 inches.

4.6.2.3 Extent of Radiographic Procedure Qualification -- Upon approval of the radiographic procedure, the Contractor will be qualified to perform radiography within the range qualified.

4.6.2.4 Requalification of Radiographic Procedure -- The radiographic procedure will be requalified when:

a. The Government Representative so directs based on a belief that the Contractor cannot meet required radiographic quality levels.

b. The X-ray machine is changed to one with a voltage rating increase of 20% or greater, or one made by a different manufacturer.

c. There is a change in the method of rectification of alternating current using a previously qualified X-ray machine.

d. The X-ray machine voltage varies 20 percent or more from that utilized during initial qualification. If the voltage used in initial qualification lies within the acceptance region of Figure 4-11, any voltage up to the maximum voltage line of Figure 4-11 may be employed on material thicknesses 0.75 inch or greater without requalifying.

e. There is a change in the type of film from extra fine grain type to fine grain type.

f. There is a reduction in the source-to-film distance beyond the minimum distance used in the approved procedure, except that requalification is not required if the source-to-film distance complies with the requirements of Figure 4-12.

4.6.2.5 Qualification Radiographs -- Qualification radiographs and copies of radiographic procedures will be retained together with certification letters and will be made available to NAVSEA or the Government Representative on request.

4.6.2.6 Transfer of Radiographic Procedure Approval -- The Contractor will request permission to use radiographic procedures and equipment previously qualified by another facility prior to utilization on 3KSES hull structure. The specific approval of NAVSEA will be required.

4.6.2.7 Survey of Approved Radiographic Facilities -- The local Government Representative (DCAS/QAR) will be permitted to perform radiographic facilities and procedures surveys annually or whenever needed to validate conformance with the requirements of MIL-STD-271.

4.6.3 ULTRASONICS PROCEDURE QUALIFICATION -- The Contractor will maintain written ultrasonic test procedures which conform to MIL-STD-271 and which will be made available to NAVSEA (or its authorized representative) on request. The procedures will be approved by

2.0% SENSITIVITY LEVEL (2-2T)

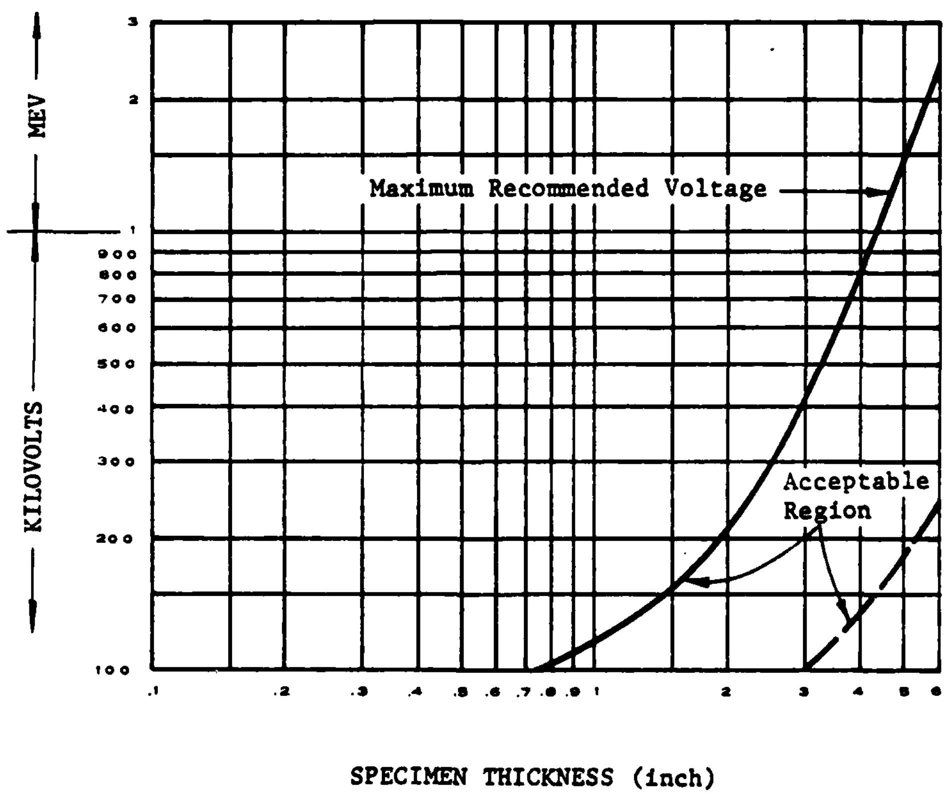
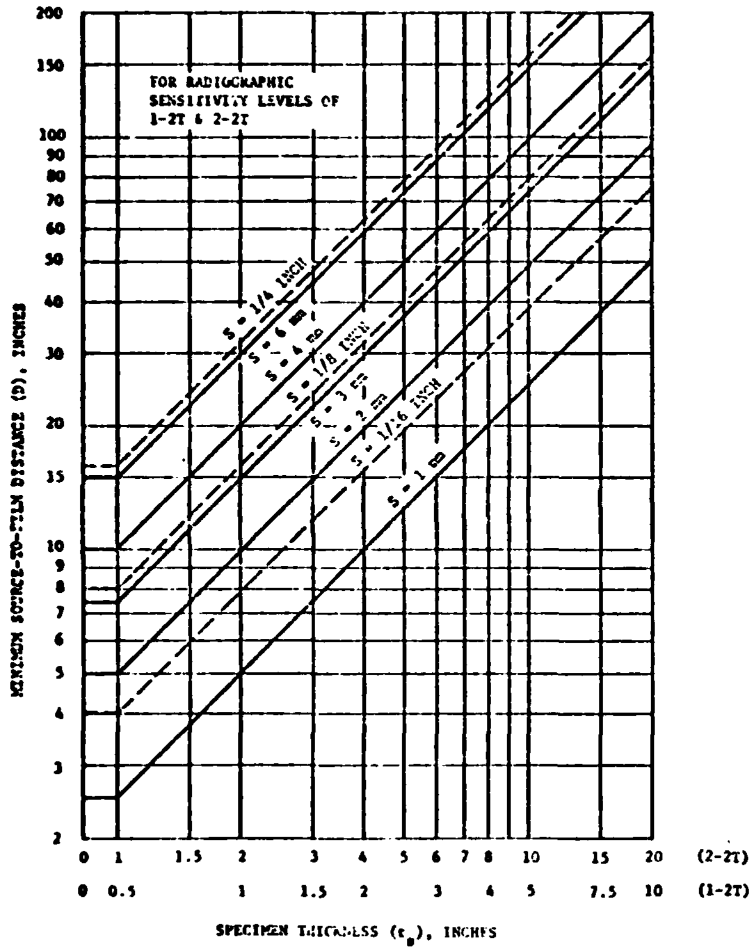


Figure 4-11. Recommended X-ray Voltage Settings for Aluminum Alloys - 3KSES



SOURCE-TO-FILM DISTANCE CALCULATION CONSTANTS		
RADIOGRAPHIC SENSITIVITY LEVEL	"K" VALUES FOR "S" (Metric System) *	"K" VALUES FOR "S" (English System) *
1-1T	7.2	11.5
1-2T	5.0	8.0
2-1T	3.6	5.7
2-2T	2.5	4.0
2-4T	2.0	3.2
4-2T	2.0	3.2

* For metric system; S = number of mm.
For english system; S = number of 1/16 inch.

NOTES: 1) The minimum source-to-film distance for a specific radiographic sensitivity level shall be calculated by the following formula:

$$D = KSt_s$$

where: D = the minimum source-to-film distance, in inches.
K = constant (see table above for applicable values of K for various sensitivity levels of inspection).
S = maximum effective focal spot dimension, in millimeters, (1 mm = 0.039 in.).
t_s = specimen thickness, in inches.

EXAMPLE: For a radiographic sensitivity level of 2-2T,

$$S = 2.5\ St_s$$

2) The film shall be as close to the specimen as possible. Where a gap between the specimen and the film holder is unavoidable, the minimum source-to-film distance (D) shall be increased in the ratio of:

$$\frac{\text{Specimen Thickness + Gap}}{\text{Specimen Thickness}}$$

Figure 4-12. Recommended Minimum Radiographic Source-to-Film Distances for Typical Maximum Focal Spot Sizes.

the designated Level III Ultrasonic Test Examiner and will have been qualified by proving that known discontinuities can be reliably detected and evaluated. Ultrasonic test procedures will contain, as a minimum, the following information:

a. Materials, shapes, or sizes to be tested or to be exempt from test.

b. Automatic defect alarm and recording equipment, or both.

c. Special search units, wedges, shoes or saddles.

d. Rotating, revolving feeding mechanisms.

e. Stage of manufacture when test will be made.

f. The surface from which the test will be performed.

g. Surface finish.

h. Couplant.

i. Method used.

j. Technique used.

k. Description of the calibration method and method of correlating indications with defects.

l. Scanning.

m. Mode of transmission.

n. Type and size of transducer.

o. Test frequency.

4.7 RADIOGRAPHIC AND ULTRASONIC EQUIPMENT CERTIFICATION

4.7.1 RADIOGRAPHIC EQUIPMENT QUALIFICATION -- The qualification of radiographic test equipment will be determined by the successful completion of the radiographic procedure approval tests per paragraph 4.6.2 of this document. Letters of radiographic procedure certification from the Norfolk Naval Shipyard will constitute certification of the

equipment with which the test radiographs were made. However, all radiographic equipment previously used for the procedure qualification tests will, under the operation of qualified operators, be capable of consistently obtaining results of the specified quality levels.

4.7.2 ULTRASONIC EQUIPMENT QUALIFICATION

4.7.2.1 Basic Instrument Qualification - Pulse Echo

a. The amplitude linearity will be checked by positioning the master transducer over the depth resolution notch in an International Institute of Welding (IIW) block or equal, so that the signal from the notch is at a height of three scale divisions (30 percent screen height), and the signal from one of the back surfaces is at a height of six scale divisions (60 percent screen height). A curve will then be plotted showing the deviations from the above established 2:1 ratio that occurs as the amplitude of the signal from the notch is raised in increments of one scale division until the back reflection signal reaches full scale, and then is lowered in increments of one scale division (10 percent) until the notch signal reaches one scale division. At each increment, the percent ratio of the two signals will be determined. The ratios will be plotted on the graph at the position corresponding to the larger signal. Between the limits of 20 and 80 percent (2 and 8 scale divisions) of the screen height, the ratio will be within 10 percent of 2:1. Instrument settings used during inspection will not cause variation outside the 10 percent limits established above.

b. The distance linearity will be determined by plotting signal displacement against known thickness in the thickness range of one to five inches in one-inch increments. For qualification, the limits will be within plus or minus three percent.

c. The resolution will be determined using the IIW steel block or equivalent with the master transducer. The equipment must resolve to the base line an 80 percent of full scale indication from the large (50 millimeter (mm)) hole 5 mm from the surface for near field resolution and the depth resolution notch for far field.

4.7.2.2 Basic Instrument Qualification - Thickness Gage -- At least two readings will be made on each of a series of test blocks representative of the range(s) of the instrument. Variations between the true thickness and the determined thickness will be reduced to plus or minus percentage variations and these values plotted on a graph. Plus or minus variation from zero will be plotted on the horizontal axis and the percent of the readings plotted on the vertical axis. A sufficient number of readings will be made to accurately determine the thickness testing characteristics of the instruments. For qualification, at least 95 percent of the total number of readings will be within plus or minus 3 percent of the true value. For thicknesses of 0.150 inch or less, the readings will be within plus or minus 0.005 inch of the true value.

4.7.2.3 Frequency of Basic Instrument Qualification -- The basic instrument qualifications will be performed and documented at intervals not to exceed 6 months or whenever maintenance is performed which may affect the equipment function.

4.7.2.4 Qualification Records -- Records of basic equipment qualifications for both the pulse-echo and the thickness gage will be signed (certified) by the designated Level III Ultrasonic Test Examiner. Records will be maintained in accordance with Section 5 of this document and will be made available to NAVSEA or the Government Representative on request.

5 / RECORD REQUIREMENTS

5.1 SCOPE

This section contains requirements for the maintenance and retention of records which document the actions performed to provide assurance of the quality of the 3KSES hull construction. These records constitute those objective evidences of quality required by MIL-Q-9858 Quality Program requirements and the 3KSES Quality Program Plan.

5.2 GENERAL

The contractor will maintain an in-house capability for meeting the requirements of this document. Written procedures will be prepared to assign responsibility and provide accountability of required records. Records will be required to the extent specified in this section.

5.3 QUALIFICATION RECORDS

Written records of inspections and tests will be maintained as required below.

5.3.1 WELDING PROCEDURE QUALIFICATION -- These records will consist of the approved welding procedure qualification test reports required by paragraph 4.3.6 of this document.

5.3.2 WELDER AND WELDING OPERATOR QUALIFICATION -- These records will consist of the Welder/Welding Operator Performance records, both individual and summary, as required by paragraph 4.4.4 of this document. Annual vision test records will be a part of the Welder/Welding Operator Performance Record.

5.3.3 NON-DESTRUCTIVE TEST PROCEDURE QUALIFICATION -- These records will consist of the liquid penetrant, radiographic and ultrasonic test procedure qualifications specified in paragraph 4.6 of this document. Radiographic qualification records will consist of the letter(s) of certification from the Norfolk Naval Shipyard which provides notification of the acceptability of the Contractor's radiographic procedures and film processing techniques. Ultrasonics procedure and liquid penetrant procedure qualification records will consist of the procedures certified by the designated Level III Examiner.

5.3.4 NON-DESTRUCTIVE TESTING PERSONNEL QUALIFICATION -- Qualification records will be maintained for all personnel who are qualified for Non-Destructive Test in conformance with paragraph 4.5 of this document. Such records will include the following information:

a. Identification (Name, employee number, social security number).

b. Date of qualification.

c. NDT process(s) in which qualified; e.g. visual, liquid penetrant, radiography and/or ultrasonic.

d. Level of qualification for each NDT process.

e. Written and practical test scores.

f. Vision test results.

g. Certifying examiners signature.

Records of training and applicable work experience will also be maintained for all personnel qualified for Non-Destructive Test in conformance with paragraph 4.5 herein.

5.3.5 NON-DESTRUCTIVE TEST EQUIPMENT QUALIFICATION -- These records will consist of the radiographic and ultrasonic equipment qualifications specified in paragraph 4.7 of this document. Radiographic equipment qualification records will consist of the letter(s) of certification from Norfolk Naval Shipyard that radiographic equipment owned by the Contractor complies with the requirements of MIL-STD-271. Ultrasonic equipment qualification records will consist of the records of basic equipment (pulse echo and thickness gage) which are certified by the designated Level III Ultrasonic Examiner.

5.4 MATERIAL RECORDS

These records will consist of the documentation of inspections and tests performed on materials in compliance with the requirements of Section 10 of this document. These records will include the following:

a. Purchasing data

b. Receiving inspection data

c. Mill and foundry certifications

d. Contractor verification test data and results

e. Records of disposition of non-conforming material and inadequate documentation.

Traceability from certifications to purchase orders and lots of material in store will be maintained; however traceability from material in store to the location of utilization within the hull structure is not required.

5.5 PRODUCTION INSPECTION RECORDS

5.5.1 NON-DESTRUCTIVE TESTS -- Records of all non-destructive tests (except visual) will be maintained. These records will include the following data:

a. Inspection method.

b. Name and number of part inspected.

c. Specific location of weld joint inspected (relative to a traceable reference location).

d. Test result by class.

e. Repair cycles -- number of repairs and method prior to acceptance.

f. Inspector's signature or stamp and the date.

g. For radiographs or ultrasonic records, an identifying number will be assigned and a physical record of the test shall be retained.

The above record requirements will also apply to non-destructive tests performed after repairs are made.

5.5.2 WORKMANSHIP -- A record of the inspection of the quality and completeness of workmanship, including visual inspection of welding, of the hull construction will be continuously maintained with evidence of sign off by Production and Quality Assurance personnel of each manufacturing operation as completed. Inspection points for Manufacturing, Quality Assurance and the Government Representative will be inserted in each Manufacturing Plan prior to release for fabrication. A file of completed, signed-off Manufacturing Plans will be maintained.

5.6 MATERIAL REVIEW BOARD RECORDS

Records of nonconformance and the corresponding dispositions by the Material Review Board or the Senior Material Review Board will be maintained in accordance with the RMI Quality Program Plan approved for use during Part II of the 3KSES Contract. A file of completed, signed off MRB records will be maintained.

5.7 MAINTENANCE OF RECORDS -- All required records will be maintained by the Contractor and will be available to the Government Representative throughout the life of the contract and for three years after delivery of the ship. At expiration of the record retention period, written notification of the availability of all records will be made to NAVSEA or its authorized representative. If no disposition is authorized within six months, the records may be destroyed.

6 / INSPECTION REQUIREMENTS

6.1 SCOPE

This section contains the requirements for inspection of the welding and workmanship in fabrication of the 3KSES hull structure. The areas to be inspected, the extent and type of inspection, and the required inspection records are specified in this section.

6.2 METHODS AND ACCEPTANCE STANDARDS

Record keeping requirements, inspection methods and acceptance standards are covered in Sections 5, 7 and 8, respectively of this document.

6.3 MATERIALS

Inspection, certification and verification of hull structural materials will be as specified in Section 10 of this document.

6.4 GENERAL

6.4.1 INSPECTION PHILOSOPHY -- Weld quality is primarily dependent on the adherence to approved weld procedures, the use of qualified welders/welding operators, and the use of materials of known properties and equipment with established characteristics. The use of orderly procedures and processes, including monitoring and verification of all weld parameters, is a prerequisite to adequate weld quality. Product

inspection, both in process and of completed weldments, is intended to give the confidence and assurance that procedures, processes, personnel, material and equipment are as specified and that the resultant product has a high probability of conformance to the acceptance standards on which design parameters are based.

The scope of inspection contained herein is considered the minimum necessary to establish confidence that the required process control has been achieved. Since complete inspection of all workmanship by all methods is not realistic, it is essential to segregate and identify critical areas for inspection emphasis, and to reduce or eliminate redundant and irrelevant operations.

6.4.2 CLASSIFICATION OF STRUCTURAL JOINT WELDS -- Structural joints will be classified as "critical" or "non-critical" for the purpose of establishing both the extent and type of inspection to be performed.

6.4.2.1 Critical Structural Welds -- The following criteria will be applied, as appropriate, to establish those welds to be designated as "critical". More than one criteria may apply to a single weld. Structures Engineering will have responsibility for making final determination of the welds which are designated "critical".

a. Joints in major structural components such as bulkheads, decks or shell plating which provide single load paths.

b. Joints subjected to high tensile stresses due to ship primary loads (hogging, sagging or torsional loads).

c. Joints subjected to high tensile stresses due to local bending.

d. Interface joints where crack propagation could constitute a serious problem.

e. Joints designated "fatigue-sensitive" as defined in Section 15 of this document.

6.4.2.2 Non-Critical Structural Welds -- Welded joints other than those described above in paragraph 6.4.2.1 will be considered "non-critical" for purposes of inspection.

6.4.2.3 Designation of Critical Welds -- Welds to which the criteria of paragraph 6.4.2.1 apply will be clearly identified as "critical" welds on the structural drawings. Welds which are designated "critical" for the full length will be identified on the drawings by placing the letters "CR" in the tail of the welding symbol used to specify the weld. When only a portion of weld is designated "critical", this will be identified in the drawing by placing the letters "CR" adjacent to the weld and specifying the extent (length) of the weld which is designated as "critical". The drawing designations for those welds considered to be fatigue sensitive as defined in Section 15 of this document will be expanded to "CR/FSA" or "CR/FSB" as applicable. All welds which are not designated "CR", "CR/FSA" or "CR/FSB" on the drawings will be considered non-critical for purposes of inspection.

6.4.3 INSPECTION RECORDS -- Records of inspection will be maintained as required in Section 5 of this document.

6.5 VISUAL INSPECTION (VT)

Visual inspection will be made prior to the accomplishment of other non-destructive tests. Visual aids (other than corrective eyeglasses) are not normally used, but the inspector may elect to use a 5X magnifier for further examination of suspect indications in welds designated "critical" to establish whether defects are present. Other physical aids such as gages, profilometers, and other instruments to establish dimensional conformance may be employed as needed.

6.5.1 BASE MATERIAL -- All base material will be visually examined prior to welding to assure proper identification to specification and thickness, and conformity to other dimensional requirements. Base material will be examined to assure cleanliness and freedom from grease, oil, primer or other surface contaminants.

6.5.2 WELD INSPECTION -- Welds will be visually inspected and accepted before other non-destructive tests are performed. Brushing and grinding will be permitted to remove surface irregularities and imperfections and to restore weld profile to appropriate contour and dimensions prior to visual inspection by an inspector. Backgouging and rewelding, including build-up, will not be performed prior to visual inspection except as authorized by Quality Engineering.

6.5.3 WELDMENT INSPECTION -- Weldment inspection will include examination for conformance of the assembly to drawing requirements relative to geometry, location, and dimensions of the as-welded parts.

6.5.4 WORKMANSHIP -- Workmanship inspection will include examination for compliance of edge preparation with weld procedure requirements, for maintenance of joint offsets within design limits, for adherence to proper orientation of plates and stiffeners, for compliance of distortion and-fairness with design parameters, for removal of weld residues, and for compliance with surface finish requirements.

6.6 LIQUID PENETRANT INSPECTION (PT)

6.6.1 GENERAL -- Liquid penetrant inspection will be used on the 3KSES hull structure as specified below in paragraph 6.6.2. Liquid penetrant inspection may also be used where radiography is required but is not feasible due to the lack of accessibility or where so directed by the MRB to aid in the evaluation of a specific condition. Liquid penetrant inspection will be accomplished using personnel and procedures which are qualified in accordance with the requirements of Section 4 of this document. Methods will conform to Section 7 and acceptance standards will conform to Section 8 of this document.

6.6.2 WEIGHT HANDLING FITTINGS -- Completed welds in or to weight handling fittings and the welds attaching weight handling fittings to the hull structure will be liquid penetrant inspected. The acceptance criteria specified in Section 8 of this document will be used for evaluation of any discontinuities detected by liquid penetrant inspection.

6.7 RADIOGRAPHIC INSPECTION (RT)

The specific areas to be radiographed and the extent of such areas will be as specified in this section and summarized in Table 6-1. Radiographic inspection will be performed by personnel qualified in conformance with the requirements of Section 4 of this document using methods described in Section 7. The acceptance criteria specified in Section 8 of this document will be used for evaluation of discontinuities detected by radiographic inspection. Unless otherwise specified, a radiograph will be a minimum of 9 inches in length, or if the area to be inspected is less than 9 inches, the entire length will be inspected.

Radiographic inspection of production welds will not be performed until the weld is completed. (See COMPLETED WELD, paragraph 3.2).

6.7.1 CRITICAL WELDS -- Not less than 10% of the length of each plating weld joint designated "CR" on the hull structural drawings will be radiographically inspected. In addition to this basic requirement, 20% of the length of each plating erection butt joint designated "CR" including butts in the shell, strength decks and bulkheads will be radiographically inspected.

6.7.2 INTERSECTIONS OF BUTTS AND SEAMS -- Not less than 10% of the intersections of butts and seams in shell plating, strength decks, and strength bulkheads will be subjected to radiographic inspection on a random basis.

Table 6-1. 3KSES Weld Joint Radiographic Inspection Requirements

LOCATION ON STRUCTURE	EXTENT OF INSPECTION(1)(2)
Welds designated "critical" (CR) (para. 6.7.1)	
a. Erection butt joints and intersections in shell, bulkhead and deck plating and in stiffeners and frames.	20 percent
b. Other butt joints designated "CR"	10 percent
Other butt joints and intersections	
a. Intersections of butts and seams (Para. 6.7.2)	10 percent
b. Butt joints in shell, bulkheads and deck plating (Para. 6.7.3)	5 percent
c. All other butt joints and intersections not included above	3 percent
Closure plates and inserts	As specified in Para. 6.7.4
Repairs made by rewelding	As specified in Para. 6.7.7

(1) Extent of inspection will be based on the length of weld in plating and on the numbers of intersections, like stiffener joints and like frame joints.

(2) Any inspected area in a joint where radiographic acceptance standards are not met will be subjected to additional radiographic inspection as necessary to determine the extent of the sub-standard welding within that joint. This inspection will be extended a minimum of 6 inches beyond the indicated area of sub-standard welding at each end or to the end of the weld, whichever is less.

6.7.3 **OTHER BUTT WELDS -- Not less than 5% of the butts and seams in** shell, bulkhead and deck plating, including erection joints, which are not included in paragraphs 6.7.1 or 6.7.2 above will be subjected to radiographic inspection.

6.7.4 **CLOSURE PLATES AND INSERTS -- Not less than one 9 inch** radiograph will be taken for each closure plate or insert. A radiograph made at the intersection of a butt and a seam weld, if present, will satisfy this requirement; if no intersections are present, the radiograph will be taken at the corner of the insert or closure plate.

6.7.5 STIFFENERS AND FRAMES -- Radiographic inspection of butt welds in stiffeners and frames will be applicable only to those welds designated "CR" on the structural drawings. Unless otherwise specified, such welds will be radiographed to the same extent as the nearest plating butt weld that lies perpendicular to the particular member; however, the percentage will be applied to the number of like joints instead of the length of weld. In the case of stiffeners and frames, a full 9 inch radiograph will be made; if the joint is less than 9 inches in length, the total joint will be radiographed.

6.7.6 **PROCESS APPLICABILITY -- The extent of radiographic inspection specified in paragraphs 6.7.1 through 6.7.5 above, will apply initially to welds made using all processes. For joints made using the automatic panel welding machine only, the extent of radiographic inspection specified may be reduced, as approved by the Government Representative, after demonstration of adequate process control and weld quality.**

6.7.7 **REPAIRS MADE BY REWELDING -- Upon completion of repair to a butt weld made by backgouging and rewelding to correct defects found during any inspection, the length of repaired weld and at least 6 inches of unrepaired weld at each end of the repair will be radiographically inspected.**

6.8 ULTRASONIC INSPECTION (UT)

Those inspections specified to be made using radiography may be made using ultrasonic methods in lieu thereof provided that reinspection of repaired areas is accomplished by the same method.

6.9 INSPECTION OF STUD WELDING

At the beginning of each production set-up (stud diameter change) and/or each shift operation, five consecutively welded studs will be inspected by bending to an angle of 10° and restraightening using a bending device similar to that shown in Figure 4-6.

As an alternate to bend testing, torque tension testing using a testing apparatus similar to that shown in Figure 4-6 may be used. For 5000 series aluminum alloy studs, torque tension testing will be performed in accordance with the following table:

Thread Size	Torque (IN-LB)
1/4 - 20	20 - 23
5/16 - 18	40 - 44
3/8 - 16	70 - 75
7/16 - 14	110 - 120
1/2 - 13	170 - 180

Care is required not to damage the stud threads.

Where failures under test occur, the entire stud welding operation will be stopped, and the conditions causing failure rectified. All studs that show signs of failure will be removed, the surface of the plate/shape ground smooth, and a new stud welded and tested.

All studs which do not meet the visual acceptance standards of Paragraph 8.4.1.14 will be replaced.

7 / NONDESTRUCTIVE TEST METHODS

7.1 SCOPE

This section specifies the requirements for performing the nondestructive tests used to detect discontinuities in metals in the 3KSES hull structure.

7.2 GENERAL

The four nondestructive test methods listed below are authorized for use to the extent specified in Section 6 of this document for inspection of the 3KSES hull structure. Nondestructive test personnel and procedures will be qualified in accordance with the provisions of Section 4 prior to their utilization for acceptance inspection. Acceptance criteria will be as specified in Section 8 of this document.

a. Visual Inspection (VT).

b. Liquid Penetrant Inspection (PT).

c. Radiographic Inspection (RT).

d. Ultrasonic Inspection (UT).

7.3 VISUAL INSPECTION (VT).

Visual inspection will be performed before accomplishment of other nondestructive tests. Visual inspectors will be familiar with the requirements

of this document and referenced documents containing visual inspection requirements and criteria.

Visual inspection of completed production welds will be accomplished without the use of magnifying glasses except where specifically authorized in Section 6 of this document for clarification of questionable indications in critical welds. Corrective eyeglasses required to restore normal vision may be used where normal vision is defined as 30/30 (distance) or Jaeger #1 (close) as determined by the applicable visual test. Gages, profilometers, and other instruments necessary for dimensional checks may be used.

Visual inspection of base metal will be made with the material surface in a clean, uncoated condition. Inspection of completed welds may be made subsequent to removal of surface irregularities by mechanical means.

7.4 LIQUID PENETRANT INSPECTION (PT)

Liquid penetrant inspection of welds when required by Section 6 of this document, will be performed using only Group III penetrant in conformance with MIL-I-25135.

7.5 RADIOGRAPHIC INSPECTION (RT)

Radiographic inspection will be used for the purposes and to the extent specified in Section 6 of this document. Equipment will be qualified in accordance with Section 4 of this document. Unless otherwise permitted herein, production welds will be inspected with reinforcement intact except that surfaces may be smoothed by mechanical means to the extent necessary to remove irregularities which would tend to mask internal defects. Production welds which require removal of the reinforcement to meet surface smoothness criteria may be radiographically inspected either before or after the reinforcement is removed.

7.6 ULTRASONIC INSPECTION (UT)

Ultrasonic inspection may be used as an alternate or supplementary method to radiography as permitted by Section 6 of this document. Equipment calibration and inspection techniques will be in compliance with the requirements contained in Section 4 of this document.

8 / ACCEPTANCE STANDARDS

8.1 SCOPE

This section contains the standards for determination of the acceptability of weld surface and internal discontinuities which are detected by visual inspection and nondestructive tests of the 3KSES hull structure. These standards apply to structure fabricated from the materials specified in Section 10.

8.2 GENERAL

The requirements, including the extent and method, for inspection of welding and workmanship are contained in Section 6 of this document. Weld acceptance standards are specified herein for use with the following inspection methods:

a. Visual Inspection (VT)
b. Liquid Penetrant Inspection (PT)
c. Radiographic Inspection (RT)
d. Ultrasonic Inspection (UT)

Tolerances for joint alignment, structural fairness and deviations from the molded form are included in Section 12 of this document; workmanship requirements are included in Section 14. Characteristics which exceed applicable acceptance standards of this Section or are not in conformance with the tolerances and requirements of Sections 12 and 14, respectively,

will be identified as discrepant and will be dispositioned in accordance with the appropriate 3KSES Quality Assurance directives.

8.3 ACCEPTANCE CLASS STANDARDS APPLICABILITY

Classes 1, 2, and 3 acceptance standards for VT, PT, RT, and UT are contained in the numbered paragraphs which follow. Class 1 acceptance standards will be applied where specified in Section 4 for qualification test assemblies and in Section 15 for all inspection of Class A fatigue sensitive structures and visual inspection only of Class B fatigue sensitive structures. Class 3 acceptance standards will be applicable for the remainder of the hull structure except where other classes are required for specific areas which are identified on the structural drawings.

Certain acceptance standards which are less stringent than the Class 3 standards contained herein are being evaluated in the 3KSES Structural Panel and Element Test Program. These standards are being developed for possible application to structures subjected to low or moderate static stress levels. Pending acceptable test results the less stringent standards, when approved by NAVSEA, will be used for evaluation of the applicable structure areas.

8.4 VISUAL INSPECTION (VT)

All welding of the hull structure will comply with the engineering drawings regarding location of welds, type of joint, type of weld, joint penetration, size and other applicable requirements as detailed below. Note: Visual inspection will be performed prior to other required non-destructive tests.

8.4.1 GENERAL STANDARDS FOR ALL CLASSES

8.4.1.1 Cracks -- Welds will be free of cracks and incomplete fusion. This requirement includes the surfaces which are exposed after removal of temporary backing bars, attachments, strongbacks, run-on tabs, shrinkage welds, etc.

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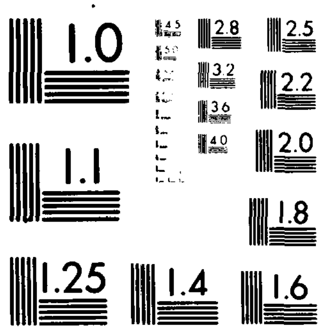

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8.4.1.2 Burn-thru -- Welds will be free of burn-thru.

8.4.1.3 Melt-thru -- Melt-thru and repaired burn-thru areas will be acceptable provided the areas do not contain cracks, crevices, excessive oxidation or globules, and provided the maximum reinforcement thickness specified in paragraph 8.4.1.8 below is not exceeded.

8.4.1.4 Oxidation -- Weld surfaces showing oxide scale accompanied by a wrinkled or crystalline appearance will be cause for rejection. However, tightly adhering thin films of oxide which do not interfere with inspection will be considered acceptable. Loose oxides which interfere with inspection will be removed by stainless steel wire brushing.

8.4.1.5 Arc-Strikes, Weld Spatter and Gouge Marks -- Welds and the adjacent base metal will be free of arc-strikes, weld spatter and gouge marks.

8.4.1.6 Contour -- The surface contour of each weld will blend into the base metal and will be free of reentrant angles. Undercut is permissible within the limits specified in the applicable Class 1, 2, or 3 requirements. When grinding or milling of the weld reinforcement is done, it will be performed so that the thickness of the weld and its adjacent base metal are not reduced more than 10% of the nominal plate thickness or 1/16 inch, whichever is less. The size and contour of fillet welds will be checked with a weld gage.

8.4.1.7 Crater Pits -- Crater pits will be acceptable provided that: (1) the area contains no cracks, (2) the root concavity and convexity limits specified in Section 14 are not exceeded, and (3) the minimum weld thickness is not less than 90% of the adjacent base metal nominal thickness.

8.4.1.8 Weld Reinforcement for Butt Joints -- The maximum thickness of weld face and root reinforcements, illustrated below in Figure 8-1, will be as specified in the applicable Class 1, 2, or 3 requirements.

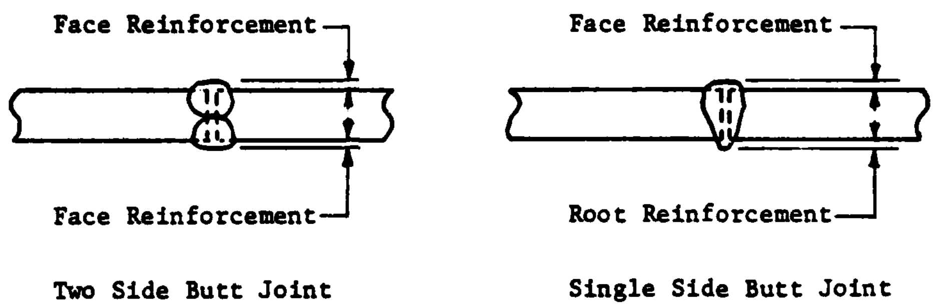


Figure 8-1. Typical Weld Reinforcements.

8.4.1.9 Welded Joint Offset -- The maximum permissible offset for all butt joints after welding will be 1/16 inch for plating thickness less than 3/8 inch and 1/8 inch for plate thicknesses 3/8 inch and greater.

8.4.1.10 Underfill and Overlap -- Welds will be free of underfill and overlap.

8.4.1.11 Fillet Weld Size -- Fillet welds will not vary below the size specified on the engineering drawing by more than 1/32 inch for 1/4 inch and smaller fillet welds and 1/16 inch for fillet welds over 1/4 inch, provided that the variance does not exceed six continuous inches and the cumulative variance does not exceed 1/4 of the fillet length. Fillet weld sizes in excess of those specified on the drawing will be avoided but are acceptable provided the contour and undercut requirements are met.

8.4.1.12 Repair Excavations and Backgouged Root Contour -- Repair excavations and backgouged root contour will be in accordance with Sections 13 and 14, respectively of this document.

8.4.1.13 Exterior Underwater Surfaces -- The exterior off-cushion underwater surfaces will be free of all projections not specifically required by the drawings. On the critical external surfaces, as defined in paragraph 12.5.2.2 below, all weld reinforcements will be milled or ground flush to the parent metal. In addition, welded joint offsets will be blended smooth with slopes not steeper than 1:10 (referenced to the adjacent plating) and with no visible steps or other surface discontinuities.

8.4.1.14 Stud Welding — A visible weld fillet encompassing at least 80% of the stud periphery is required. Cracking of the weld during production tests specified in paragraph 6.9 will constitute failure of the test.

8.4.2 CLASS I VISUAL ACCEPTANCE STANDARDS

8.4.2.1 General — The provisions of paragraph 8.4.1 above will be applicable.

8.4.2.2 Undercut — The maximum allowable weld undercut will be 1/64 inch or 10% of the adjacent base metal thickness, whichever is less.

8.4.2.3 Weld Reinforcement for Butt Joints -- Except as noted herein, the maximum weld face and root reinforcements for butt joints will be as follows:

Base Metal Thickness (in.)	Maximum Reinforcement (in.)
Up to 1/4 inclusive	1/16
Over 1/4 to 1	3/32
Over 1 to 2	1/8
Over 2	5/32

For fatigue sensitive structures, as defined in Section 15, the maximum weld face and root reinforcements will be 1/32 inch.

8.4.2.4 Porosity -- Visible porosity will not exceed the Class 1 standards specified below in paragraph 8.5.2.

8.4.3 CLASS 2 VISUAL ACCEPTANCE STANDARDS

8.4.3.1 General -- The provisions of paragraph 8.4.1 above will be applicable.

8.4.3.2 Undercut -- Except as further noted herein, the maximum allowable weld undercut will be 1/32 inch or 10% of the adjacent base metal nominal thickness, whichever is less. For base metal thickness of 1/2 inch and greater, up to 1/16 inch undercut is allowed; however, the total accumulated length of undercut which exceeds 1/32 inch will not exceed 15% of the joint length or 12 inches in any 36 inch length of weld, whichever is less.

8.4.3.3 Weld Reinforcement for Butt Joints -- The maximum allowable weld face and root reinforcements for butt joints will be 3/32 inch for base metal thicknesses 1/2 inch and under and 5/32 inch for base metal thicknesses over 1/2 inch.

8.4.3.4 Porosity -- Visible porosity will not exceed the Class 2 standards specified below in paragraph 8.5.3.

8.4.4 CLASS 3 VISUAL ACCEPTANCE STANDARDS -- The standards of paragraph 8.4.3 above will be applicable except that visible porosity will not exceed the Class 3 standards of paragraph 8.5.4 below.

8.5 LIQUID PENETRANT INSPECTION (PT)

Welds which are inspected by the liquid penetrant method as required by Section 6 and as specified in Section 7 will be free of cracks and will be subject to the applicable acceptance standards as detailed below.

8.5.1 GENERAL STANDARDS FOR ALL CLASSES

8.5.1.1 Linear Indications -- Linear indications are defined as those indications greater than 1/16 inch long whose length is equal to or greater than three times the width. All welds and at least 1/2 inch of the base metal on each side will be free of linear indications except for undercut indications within the requirements of paragraph 8.4.1.6 above. Base metal indications 1/16 inch and smaller will be acceptable. Indications 1/16 inch long and less will be considered as non-linear.

8.5.1.2 Non-Relevant Rounded Indications -- Non-linear or rounded indications which are 1/64 inch diameter or less will be acceptable for material thicknesses of 3/16 inch and less. Rounded indications 1/32 inch diameter and less will be acceptable for material thicknesses greater than 3/16 inch.

8.5.1.3 Linearly Aligned Rounded Indications -- Four or more indications in a line, any one of which is separated from the adjacent indication by less than 1/16 inch or D, whichever is greater (where D is the diameter of the larger of the adjacent indications), are defined as linearly aligned rounded indications. Acceptance criteria for linearly aligned rounded indications are specified in the applicable class standards.

8.5.2 CLASS 1 LIQUID PENETRANT ACCEPTANCE STANDARDS

8.5.2.1 General -- The provisions of Paragraph 8.5.1 above will be applicable.

8.5.2.2 Maximum Indication Size -- The acceptable size of individual non-linear or rounded indications will not exceed the limits for Class 1 in Figure 8-2.

8.5.2.3 Non-Linear Indications -- Random non-linear or rounded indications which meet the standards of Figure 8-3 for any 6-inch length of weld will be acceptable. The maximum number of indications for weld length less than 6 inches and weld width different from that shown in Figure 8-3 will be prorated. Figure 8-4 may be used to determine the total area of indications. In joints between materials of unequal thickness, the standards applied will be based on the thickness of the thinner member.

8.5.2.4 Linearly Aligned Rounded Indications -- Linearly aligned rounded indications, as defined above in Paragraph 8.5.1.3, will be cause for rejection if one or more of the aligned indications is 1/32-inch or greater in diameter.

8.5.3 CLASS 2 LIQUID PENETRANT ACCEPTANCE STANDARDS

8.5.3.1 General -- The provisions of Paragraph 8.5.1 above will be applicable.

8.5.3.2 Maximum Indication Size -- The acceptable size of individual nonlinear or rounded indications will not exceed the limits for Class 2 in Figure 8-2.

8.5.3.3 Non-Linear Indications -- Random non-linear or rounded indications which meet the standards of Figure 8-5 for a 6-inch length of weld will be acceptable. The maximum number of indications for

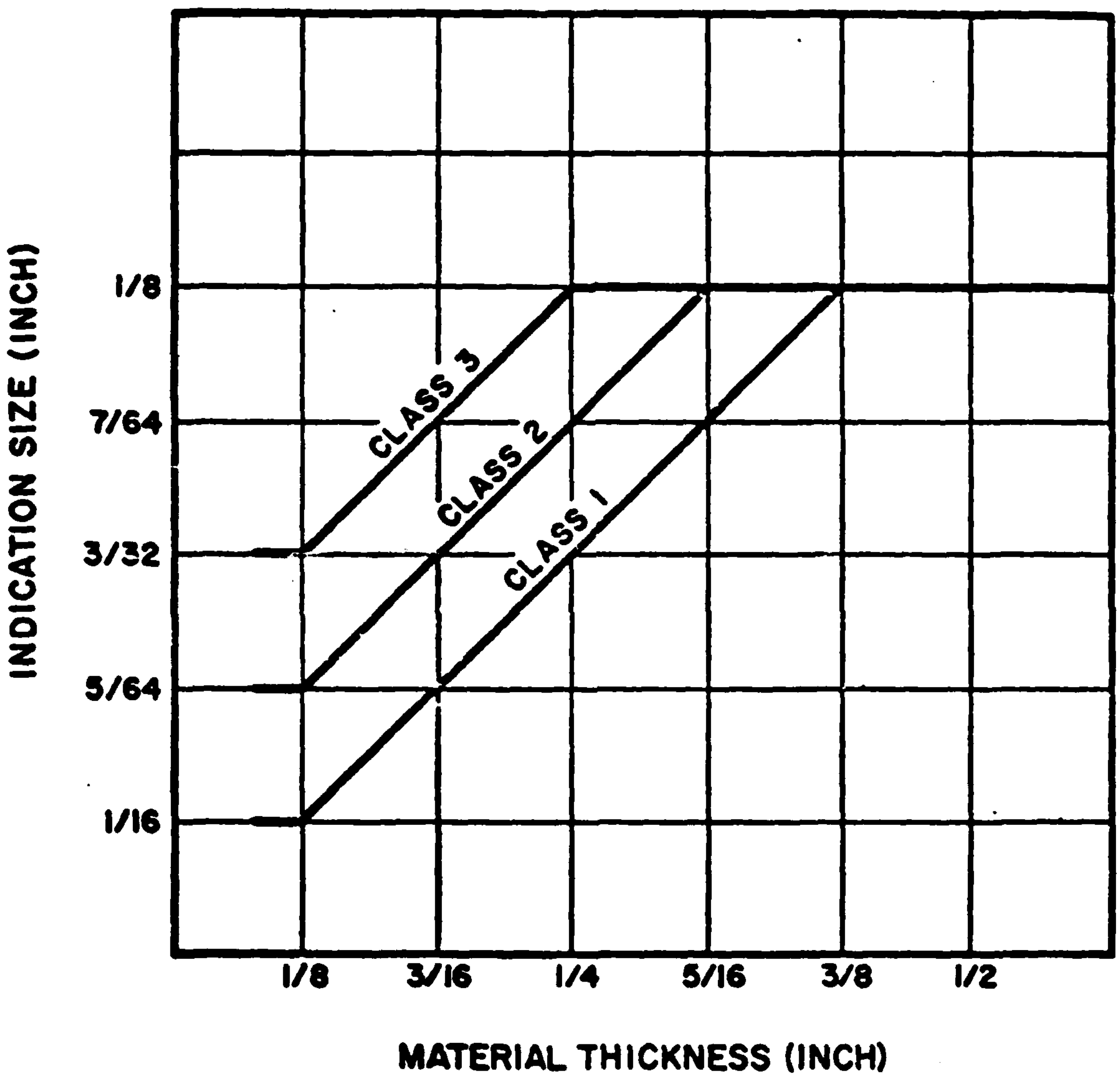


Figure 8-2. Weld Surface Inspection Standards for Maximum Permissible Size of Rounded Indications.

CLASS I WELD

(TOTAL INDICATION AREA=0.375% OF WELD SURFACE AREA)
FOR MATERIAL THICKNESS=1/8 INCH AND LESS

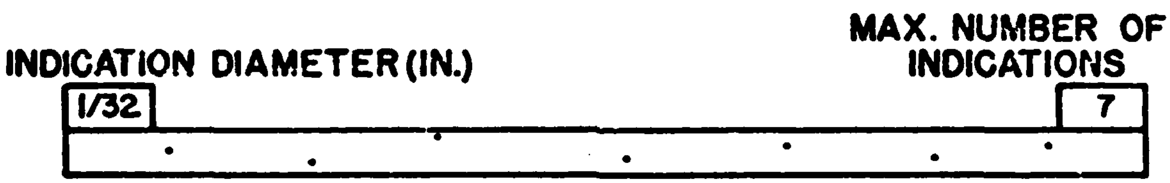


Figure 8-3. Class 1 Weld Surface Inspection Standard for Scattered Rounded or Non-Linear Indications (Sheet 1 of 6).

CLASS I WELD

(TOTAL INDICATION AREA = 0.375 % OF WELD SURFACE AREA)

FOR MATERIAL THICKNESS = 3/16 INCH

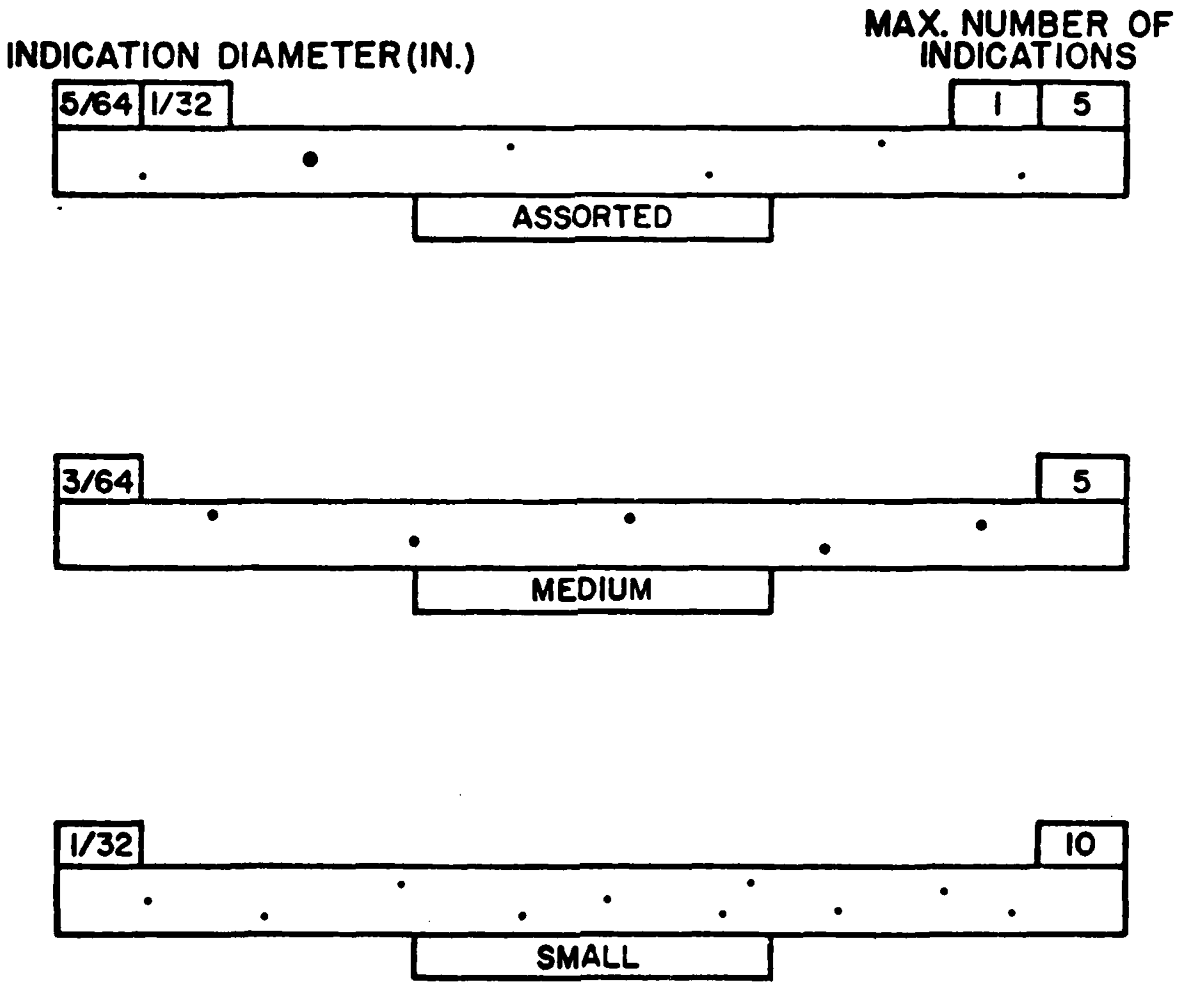


Figure 8-3. Class 1 Weld Surface Inspection Standard for Scattered Rounded or Non-Linear Indications (Sheet 2 of 6).

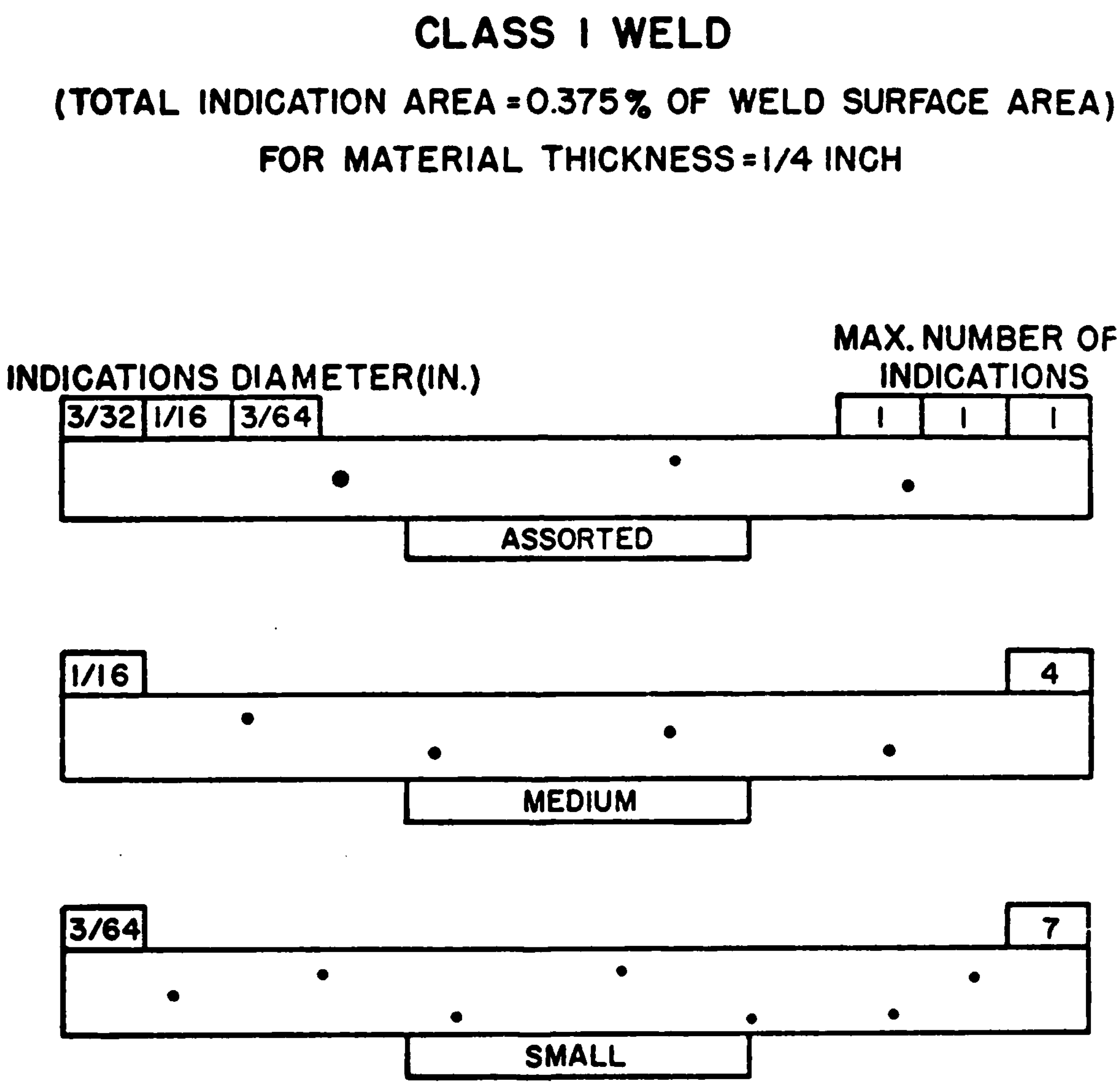


Figure 8-3. Class 1 Weld Surface Inspection Standard for Scattered Rounded or Non-Linear Indications (Sheet 3 of 6).

CLASS I WELD

(TOTAL INDICATION AREA = 0.375% OF WELD SURFACE AREA)
FOR MATERIAL THICKNESS = 3/8 INCH

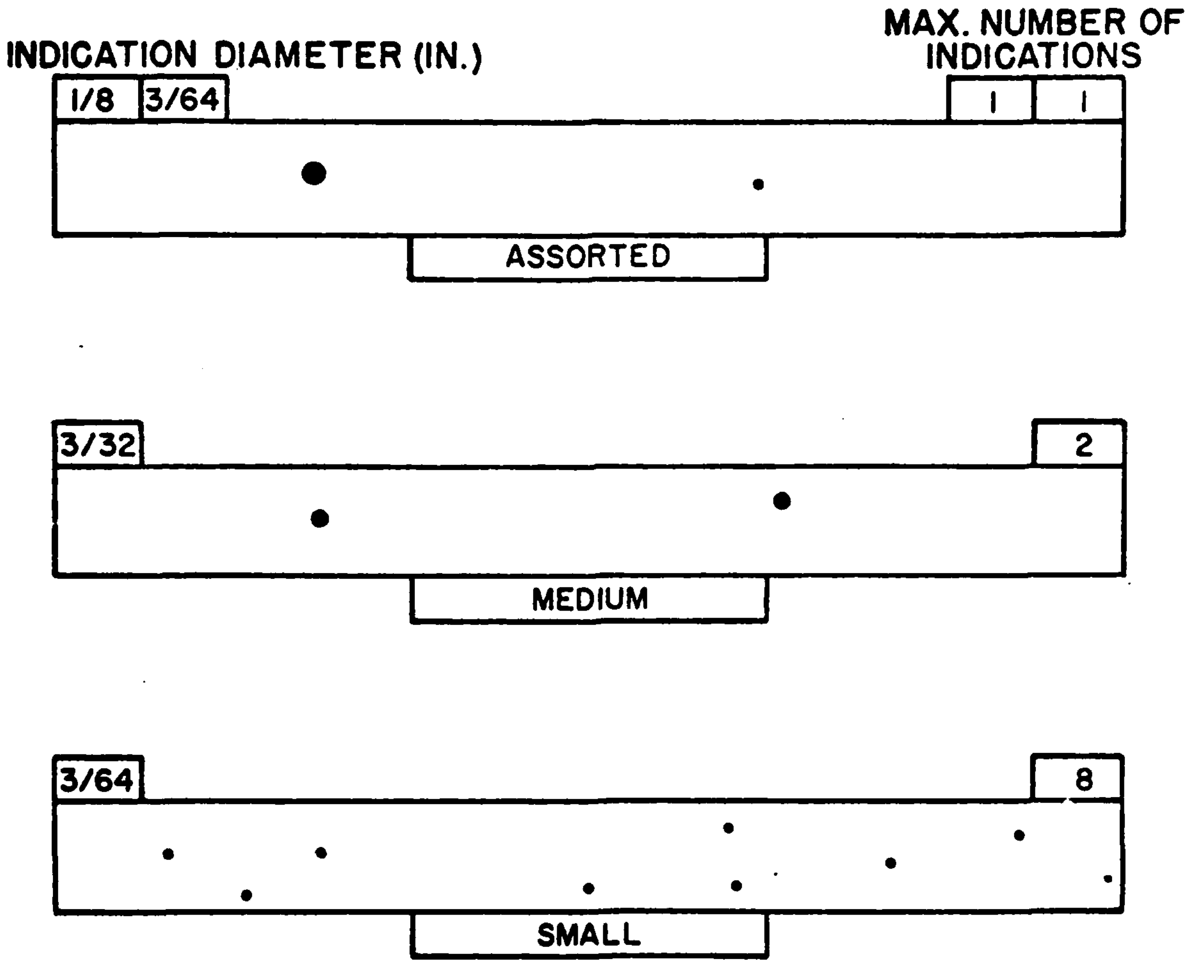


Figure 8-3. Class 1 Weld Surface Inspection Standard for Scattered Rounded or Non-Linear Indications (Sheet 4 of 6).

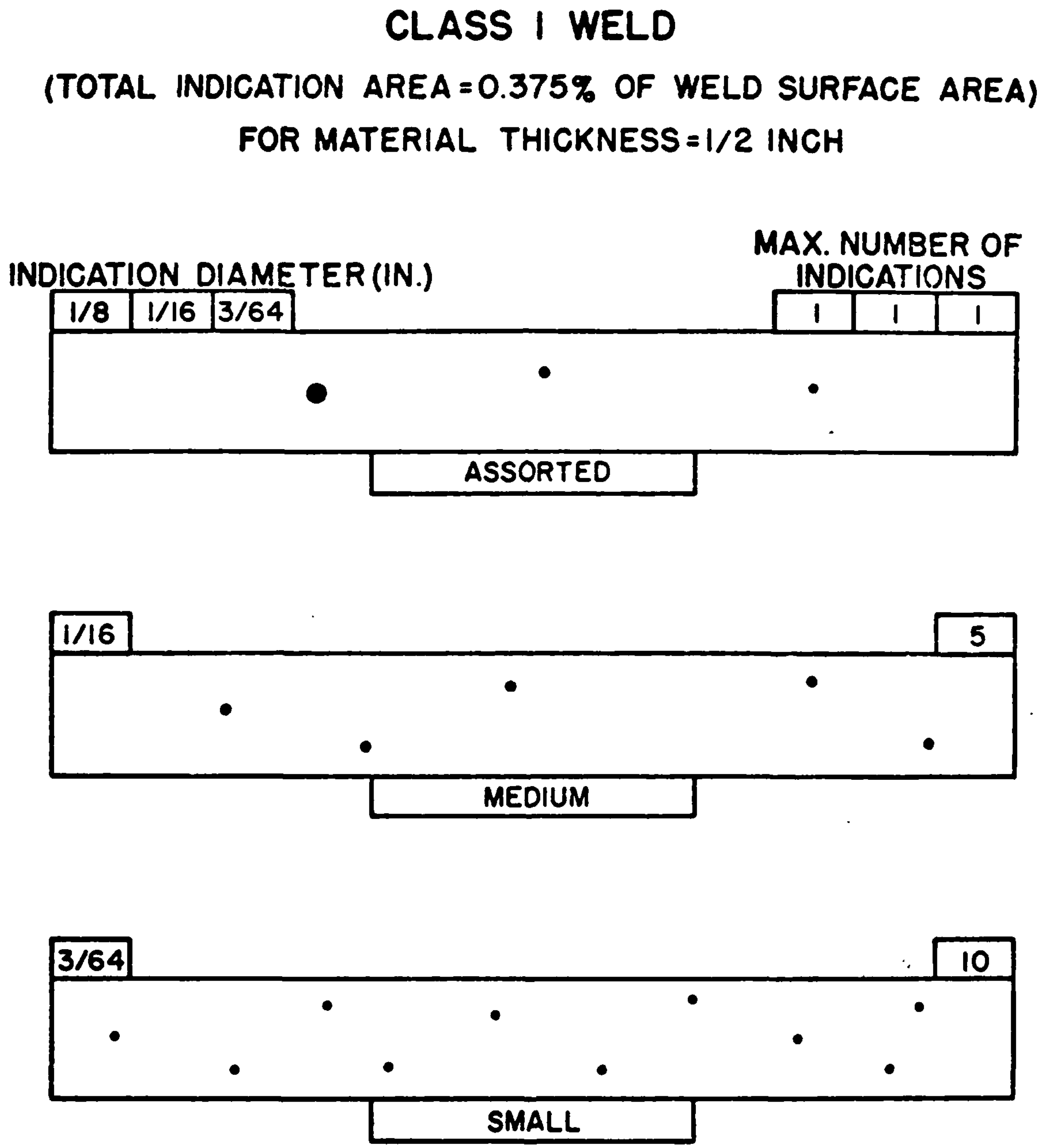


Figure 8-3. Class 1 Weld Surface Inspection Standard for Scattered Rounded or Non-Linear Indications (Sheet 5 of 6).

CLASS I WELD

(TOTAL INDICATION AREA=0.375% OF WELD SURFACE AREA)
FOR MATERIAL THICKNESS=3/4 INCH AND OVER

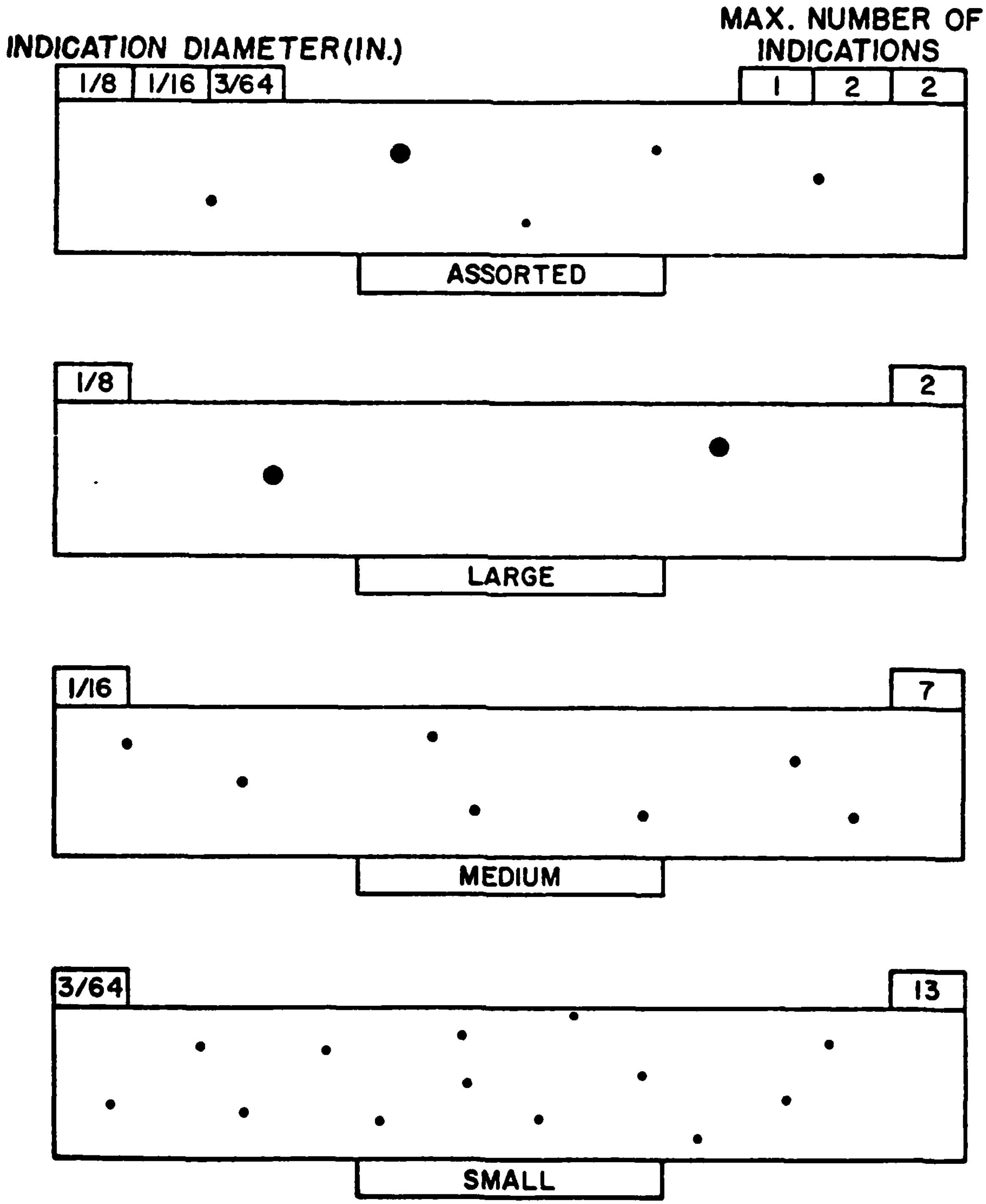


Figure 8-3. Class 1 Weld Surface Inspection Standard for Scattered Rounded or Non-Linear Indications (Sheet 6 of 6).

DIAMETER (INCHES)	AREA (SQ.IN.)	DIAMETER (INCHES)	AREA (SQ.IN.)
1/32	.0008	.0195	.0003
3/64	.0017	.020	.0003
1/16	.0031	.024	.0005
5/64	.0048	.025	.0005
3/32	.0069	.0275	.0006
7/64	.0093	.031	.0008
1/8	.0123	.034	.0009
9/64	.0155	.037	.0011
5/32	.0192	.039	.0015
11/64	.0232	.048	.0018
3/16	.0276	.049	.0019
13/64	.0324	.050	.0020
7/32	.0375	.055	.0024
15/64	.0431	.075	.0044
1/4	.0491	.078	.0047
		.100	.0079

Figure 8-4. Areas of Circles.

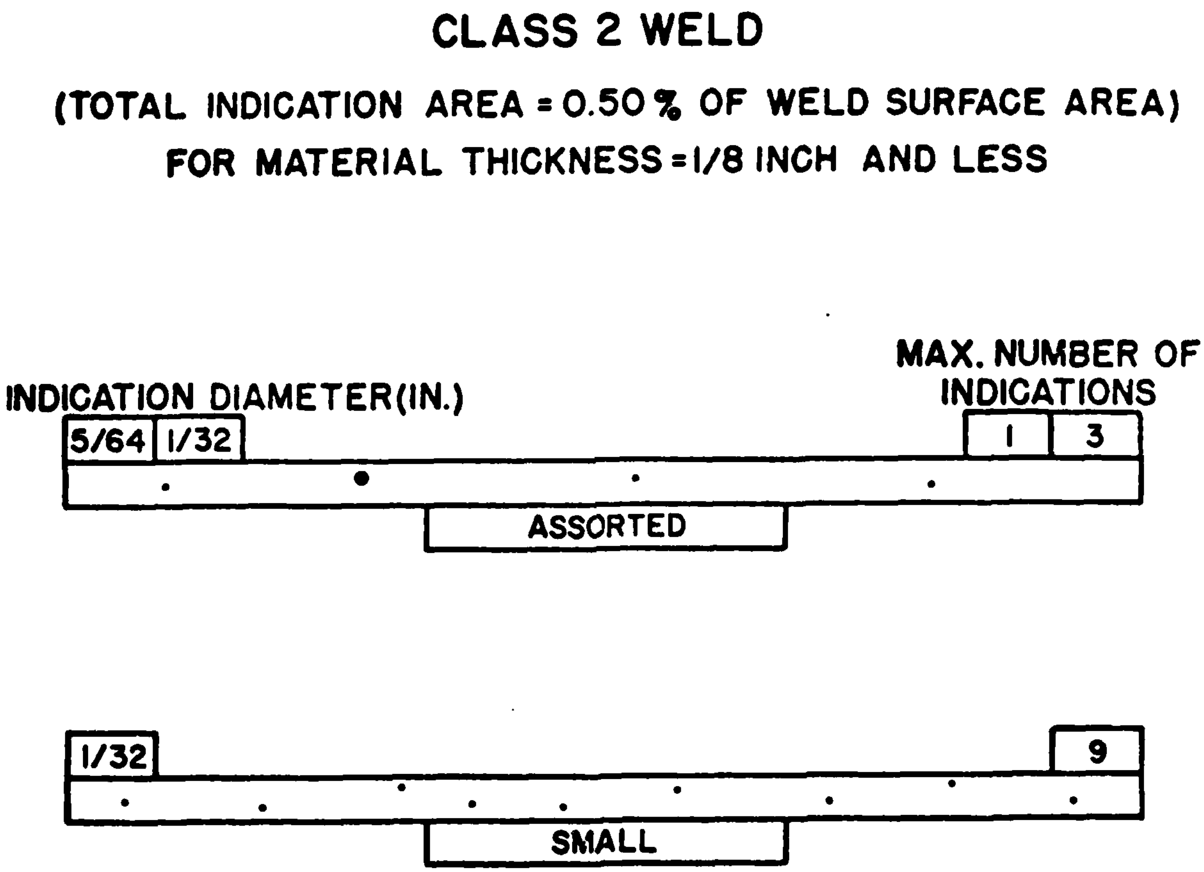


Figure 8-5. Class 2 Weld Surface Inspection Standards for Scattered Rounded or Non-Linear Indications (Sheet 1 of 6).

CLASS 2 WELD

(TOTAL INDICATION AREA = 0.50 % OF WELD SURFACE AREA)

FOR MATERIAL THICKNESS = 3/16 INCH

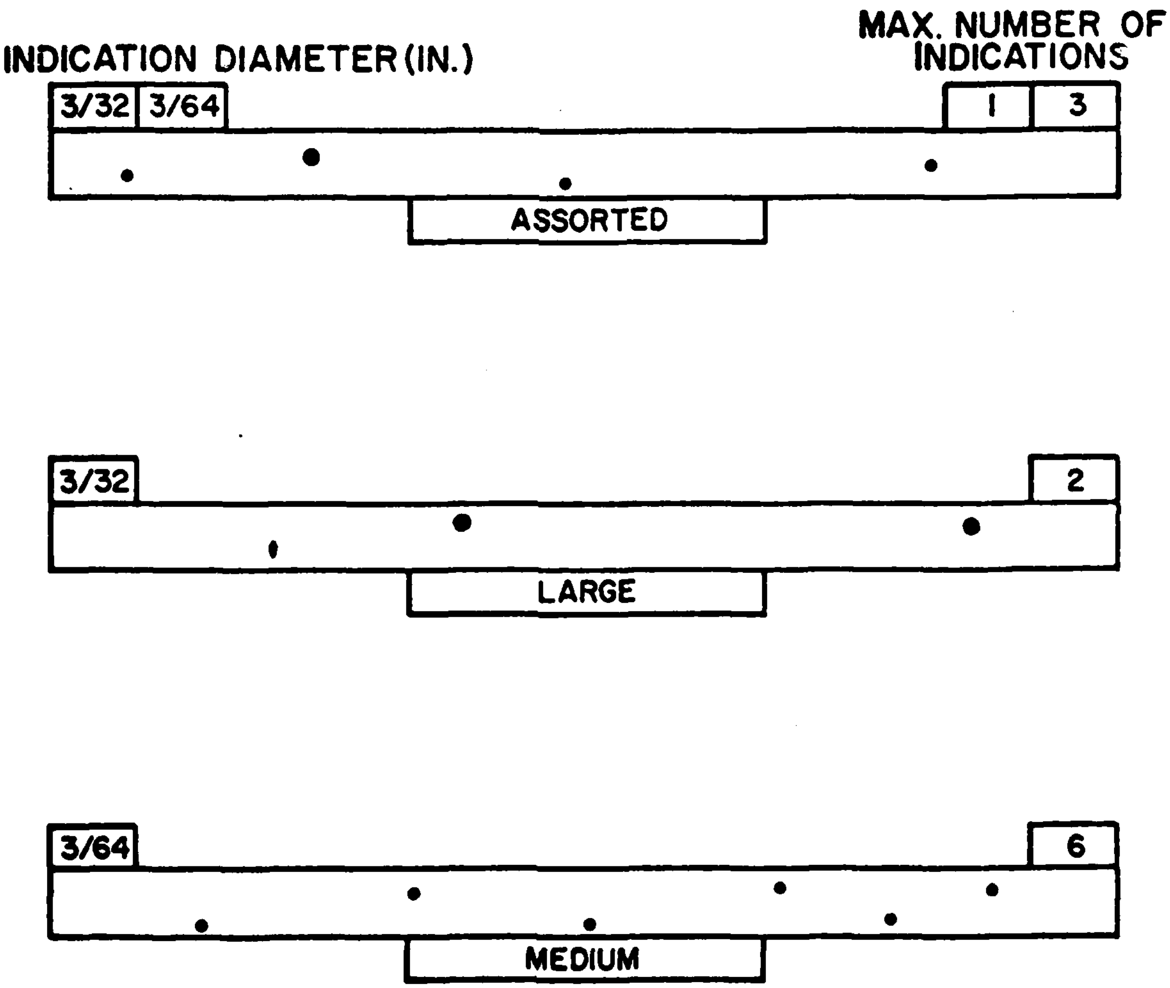


Figure 8-5. Class 2 Weld Surface Inspection Standards for Scattered Rounded or Non-Linear Indications (Sheet 2 of 6).

CLASS 2 WELD

(TOTAL INDICATION AREA = 0.50% OF WELD SURFACE AREA)
FOR MATERIAL THICKNESS = 1/4 INCH

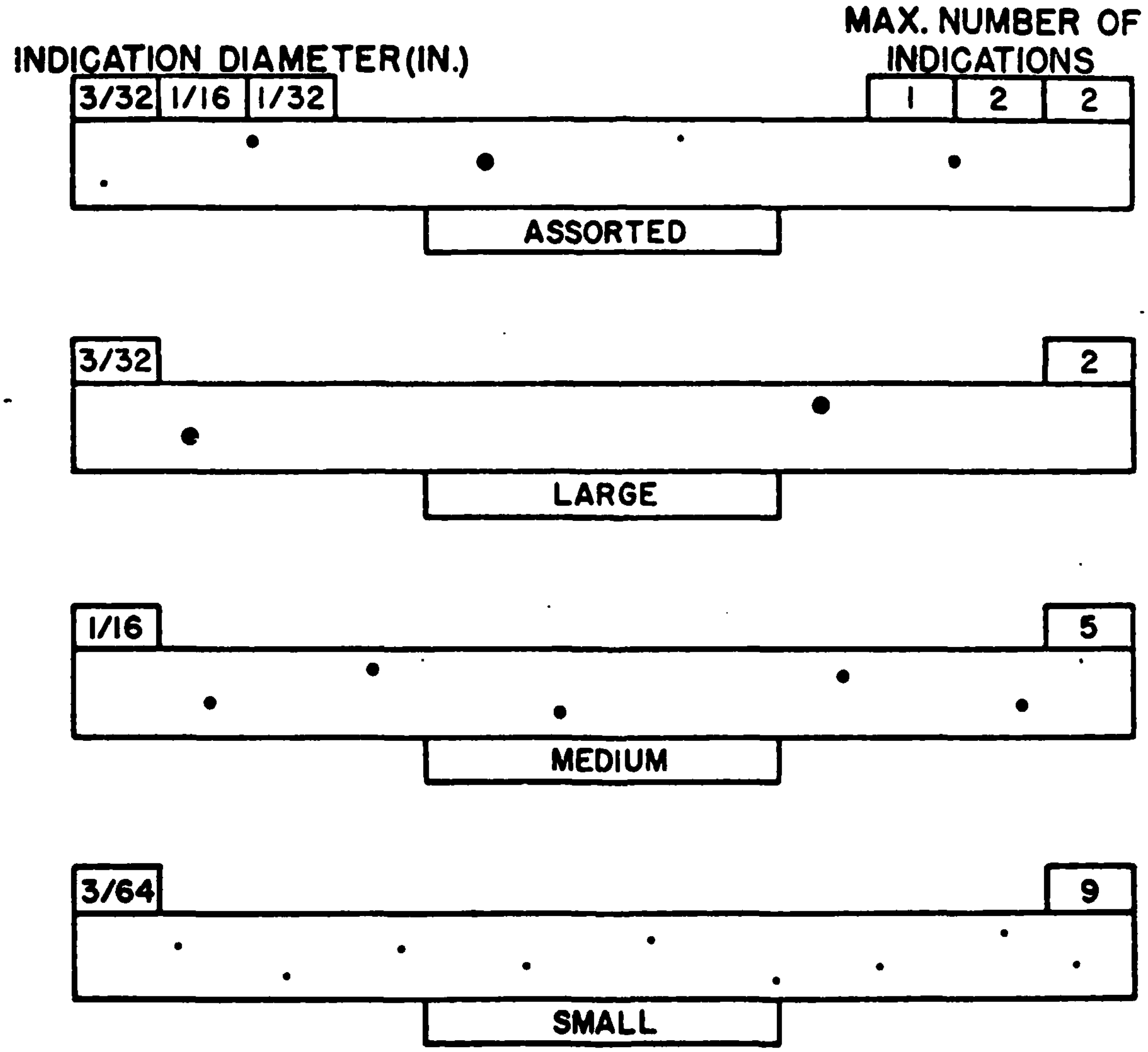


Figure 8-5. Class 2 Weld Surface Inspection Standards for Scattered Rounded or Non-Linear Indications (Sheet 3 of 6).

CLASS 2 WELD

(TOTAL INDICATION AREA = 0.50% OF WELD SURFACE AREA) FOR MATERIAL THICKNESS = 3/8 INCH

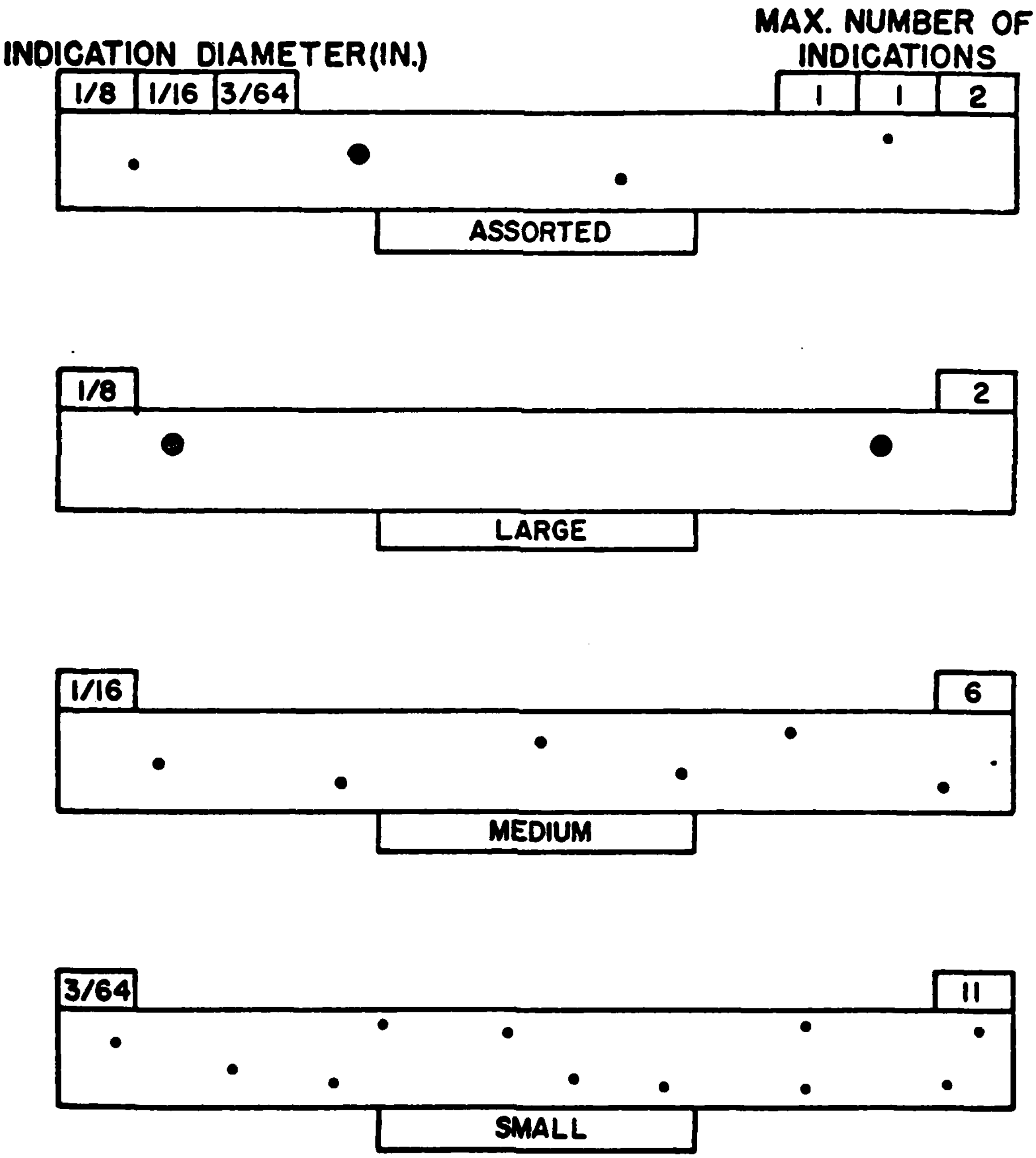


Figure 8-5. Class 2 Weld Surface Inspection Standards for Scattered Rounded or Non-Linear Indications (Sheet 4 of 6).

CLASS 2 WELD

(TOTAL INDICATION AREA = 0.50% OF WELD SURFACE AREA)

FOR MATERIAL THICKNESS = 1/2 INCH

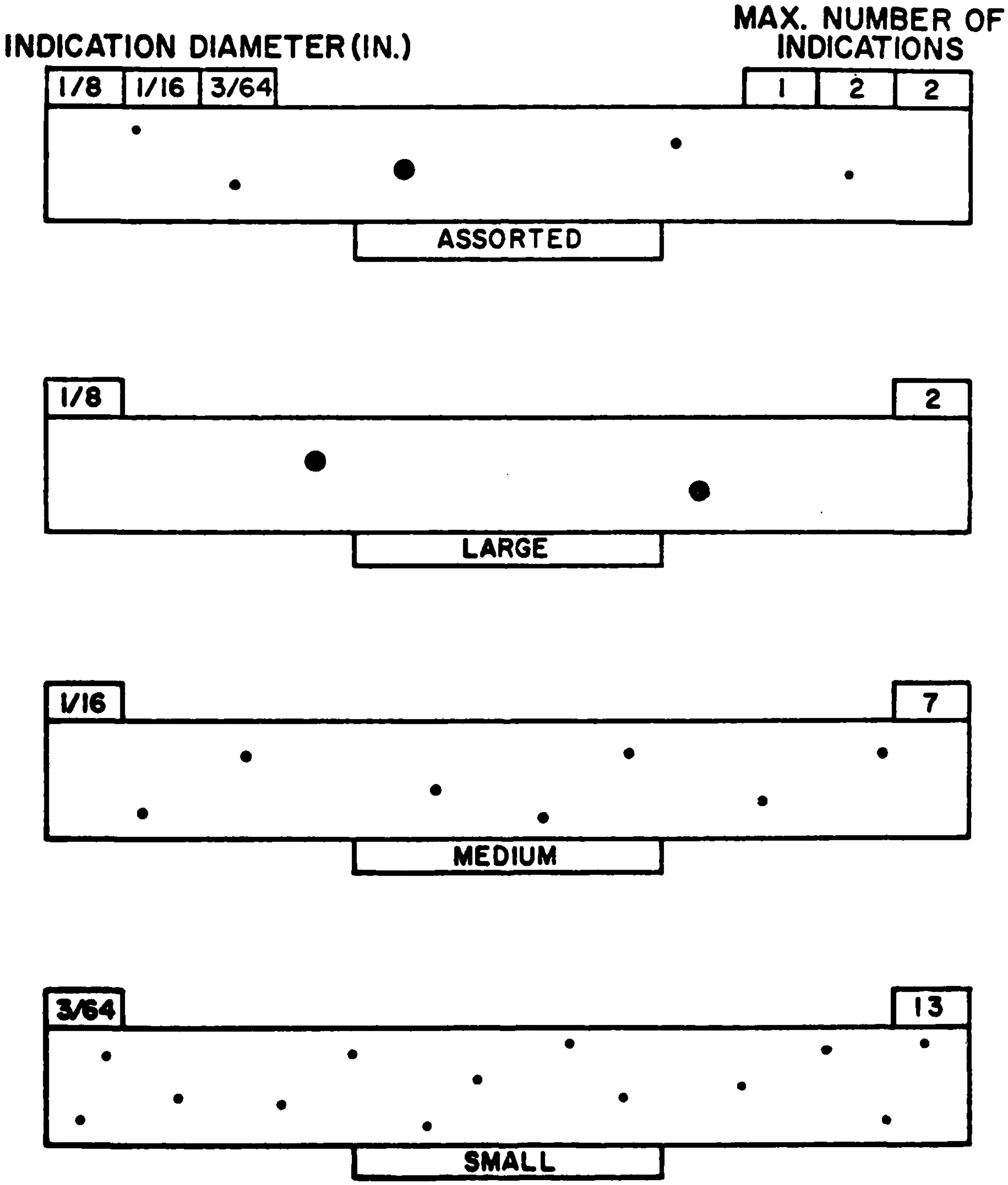


Figure 8-5. Class 2 Weld Surface Inspection Standards for Scattered Rounded or Non-Linear Indications (Sheet 5 of 6).

CLASS 2 WELD

(TOTAL INDICATION AREA = 0.50% OF WELD SURFACE AREA)

FOR MATERIAL THICKNESS = 3/4 INCH AND OVER

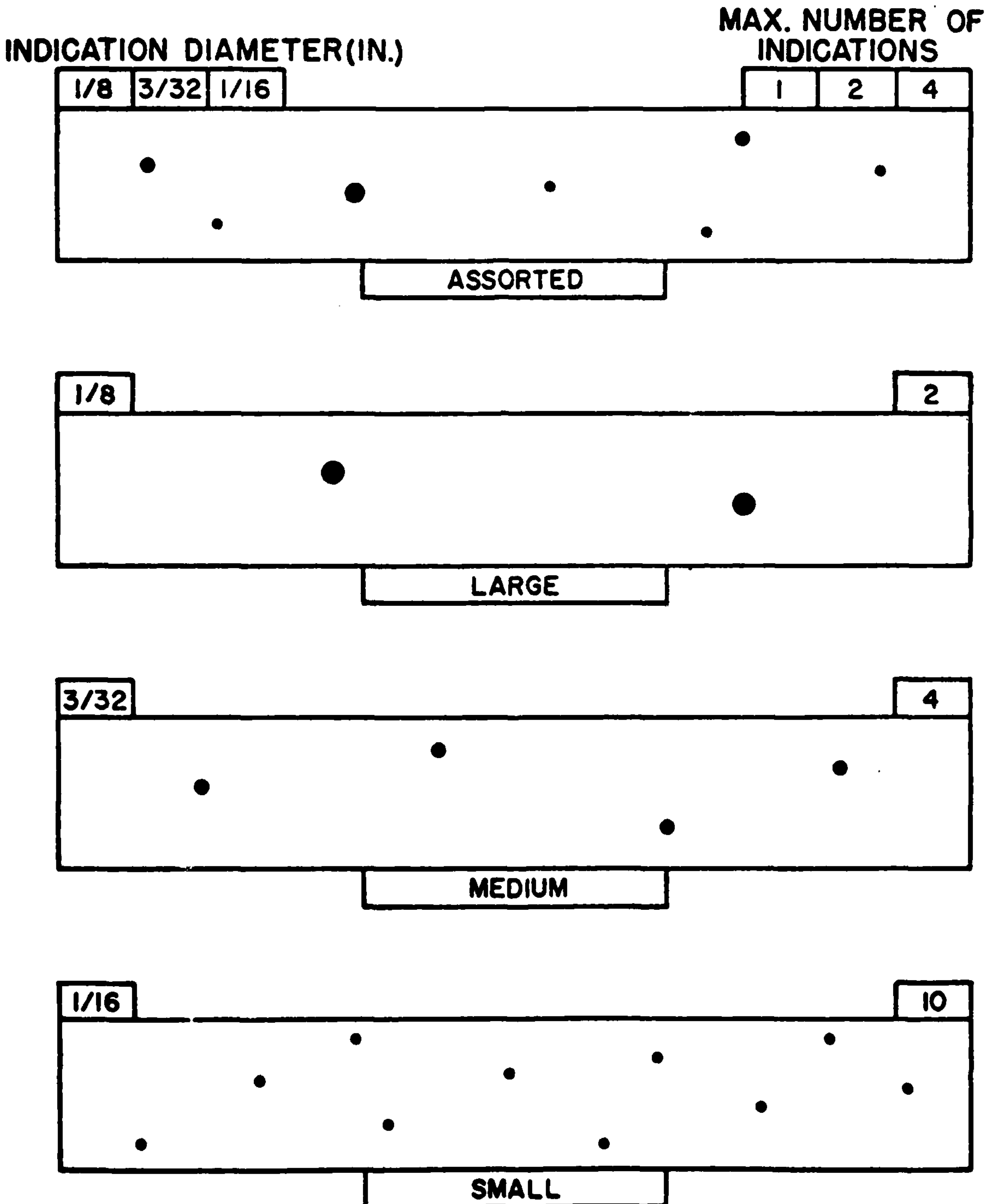


Figure 8-5. Class 2 Weld Surface Inspection Standards for Scattered Rounded or Non-Linear Indications (Sheet 6 of 6).

weld length less than 6 inches and weld width different from that shown in Figure 8-5 will be prorated. Figure 8-4 may be used to determine the total area of indications. In joints between materials of unequal thickness, the standards applied will be based on the thickness of the thinner member.

8.5.3.4 Linearly Aligned Rounded Indications -- Linearly aligned rounded indications, as defined above in Paragraph 8.5.1.3, will be cause for rejection if one or more of the aligned indications is 1/16-inch or greater in diameter.

8.5.4 CLASS 3 LIQUID PENETRANT ACCEPTANCE STANDARDS

8.5.4.1 General -- The provisions of Paragraph 8.5.1 above will be applicable.

8.5.4.2 Maximum Indication Size -- The acceptable size of individual non-linear or rounded indications will not exceed the limits for Class 3 in Figure 8-2.

8.5.4.3 Non-Linear Indications -- Random non-linear or rounded indications which meet the standards of Figure 8-6 for a 6-inch length of weld will be acceptable. The maximum number of indications for weld length less than 6 inches and weld width different from that shown in Figure 8-6 will be prorated. Figure 8-4 may be used to determine the total area of indications. In joints between materials of unequal thickness, the standards applied will be based on the thickness of the thinner member.

8.5.2.4 Linearly Aligned Rounded Indications -- Linearly aligned rounded indications, as defined above in Paragraph 8.5.1.3, will be cause for rejection if one or more of the aligned indications is 3/32-inch or greater in diameter.

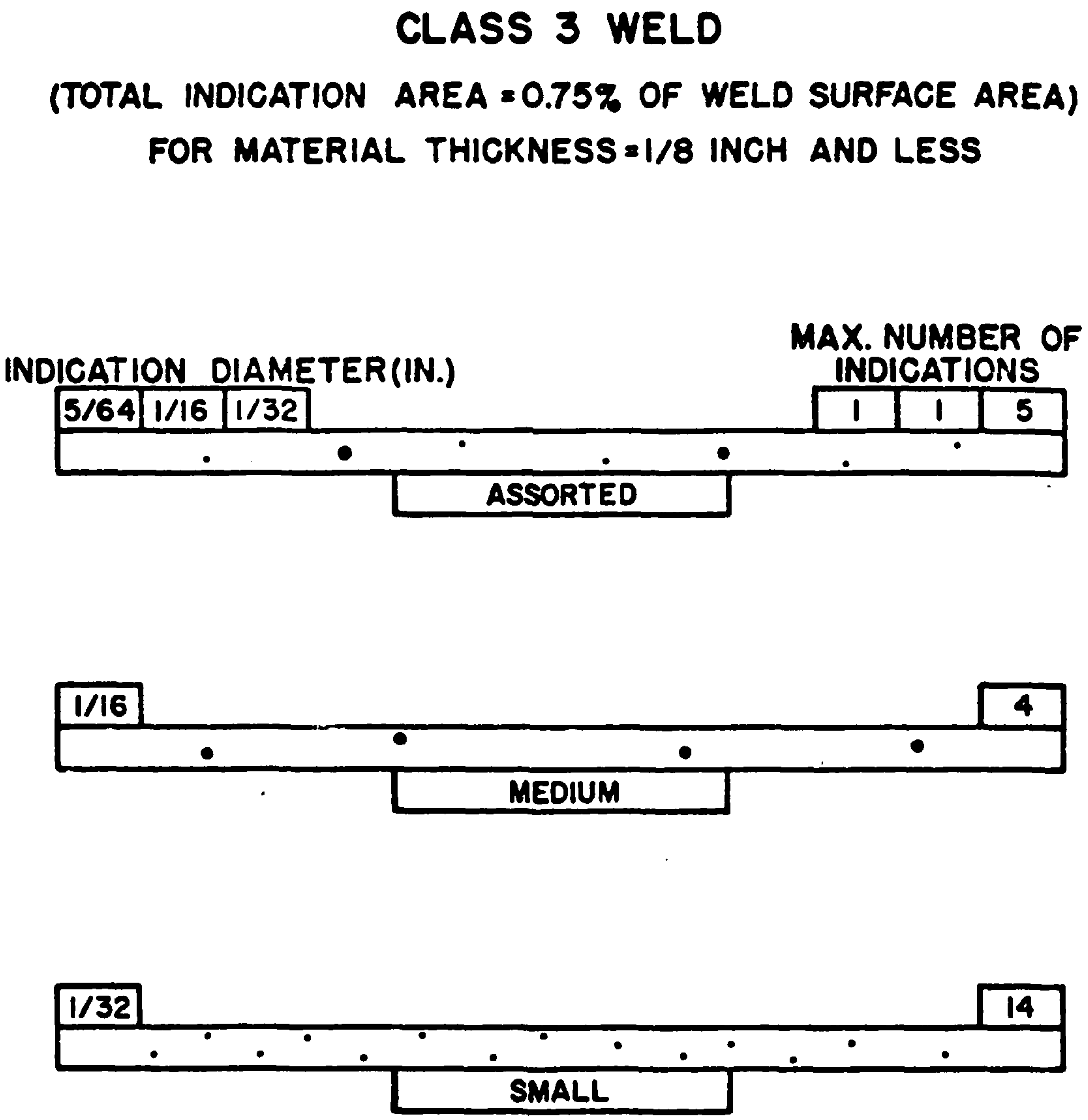


Figure 8-6. Class 3 Weld Surface Inspection Standards for Scattered Rounded or Non-Linear Indications (Sheet 1 of 6).

CLASS 3 WELD

(TOTAL INDICATION AREA = 0.75% OF WELD SURFACE AREA)
FOR MATERIAL THICKNESS = 3/16 INCH

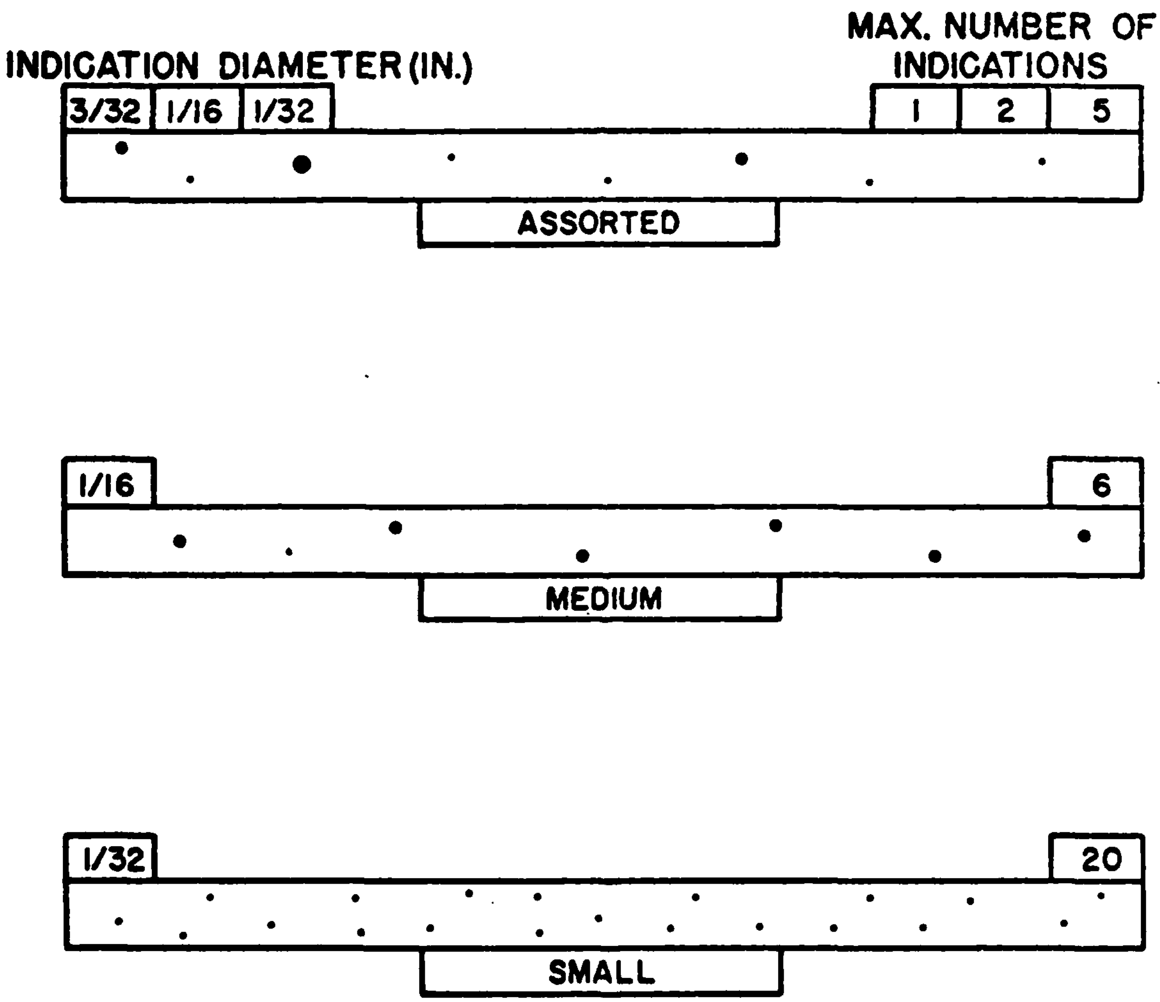


Figure 8-6. Class 3 Weld Surface Inspection Standards for Scattered Rounded or Non-Linear Indications (Sheet 2 of 6).

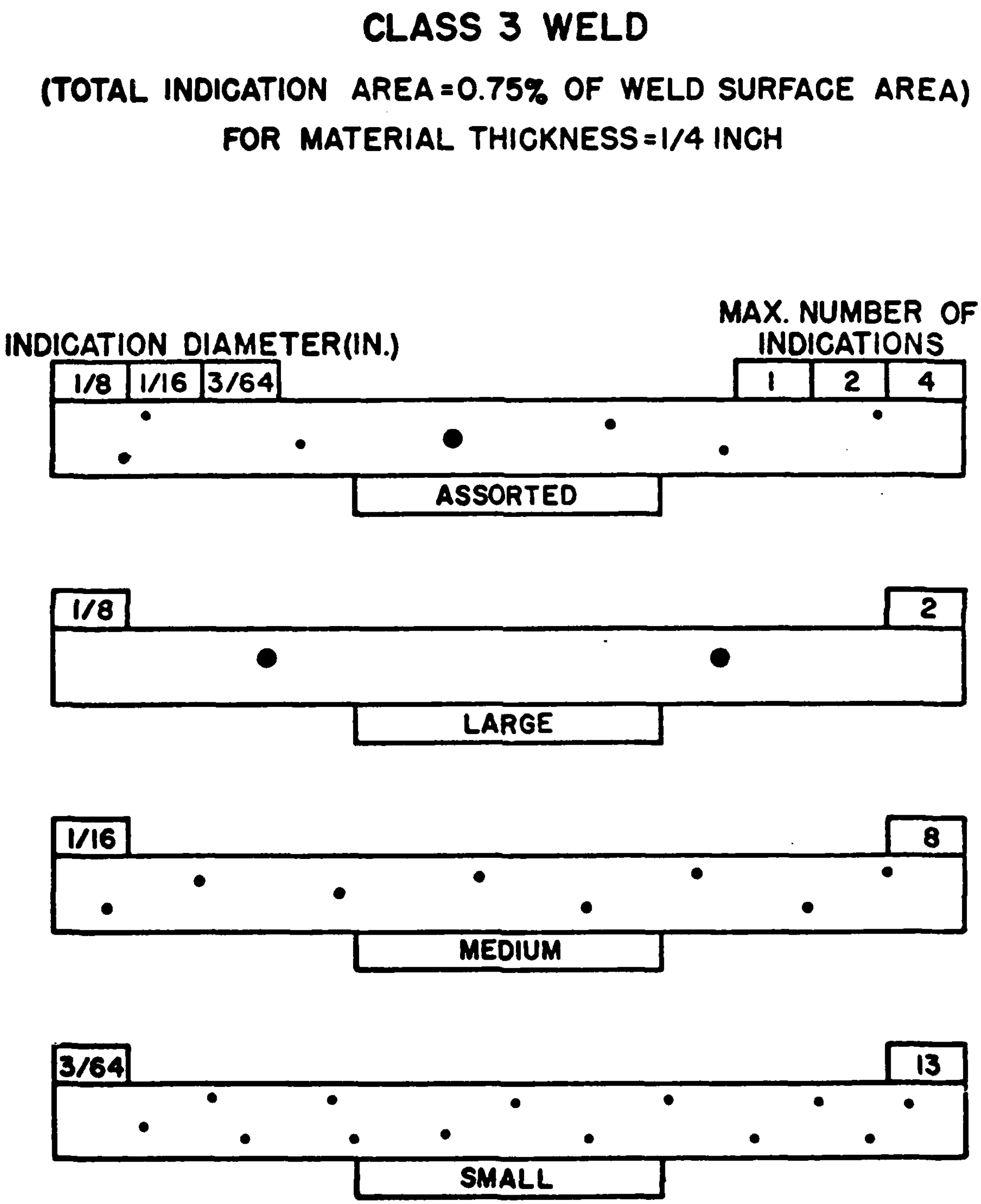


Figure 8-6. Class 3 Weld Surface Inspection Standards for Scattered Rounded or Non-Linear Indications (Sheet 3 of 6).

CLASS 3 WELD

(TOTAL INDICATION AREA = .075% OF WELD SURFACE AREA)
FOR MATERIAL THICKNESS = 3/8 INCH

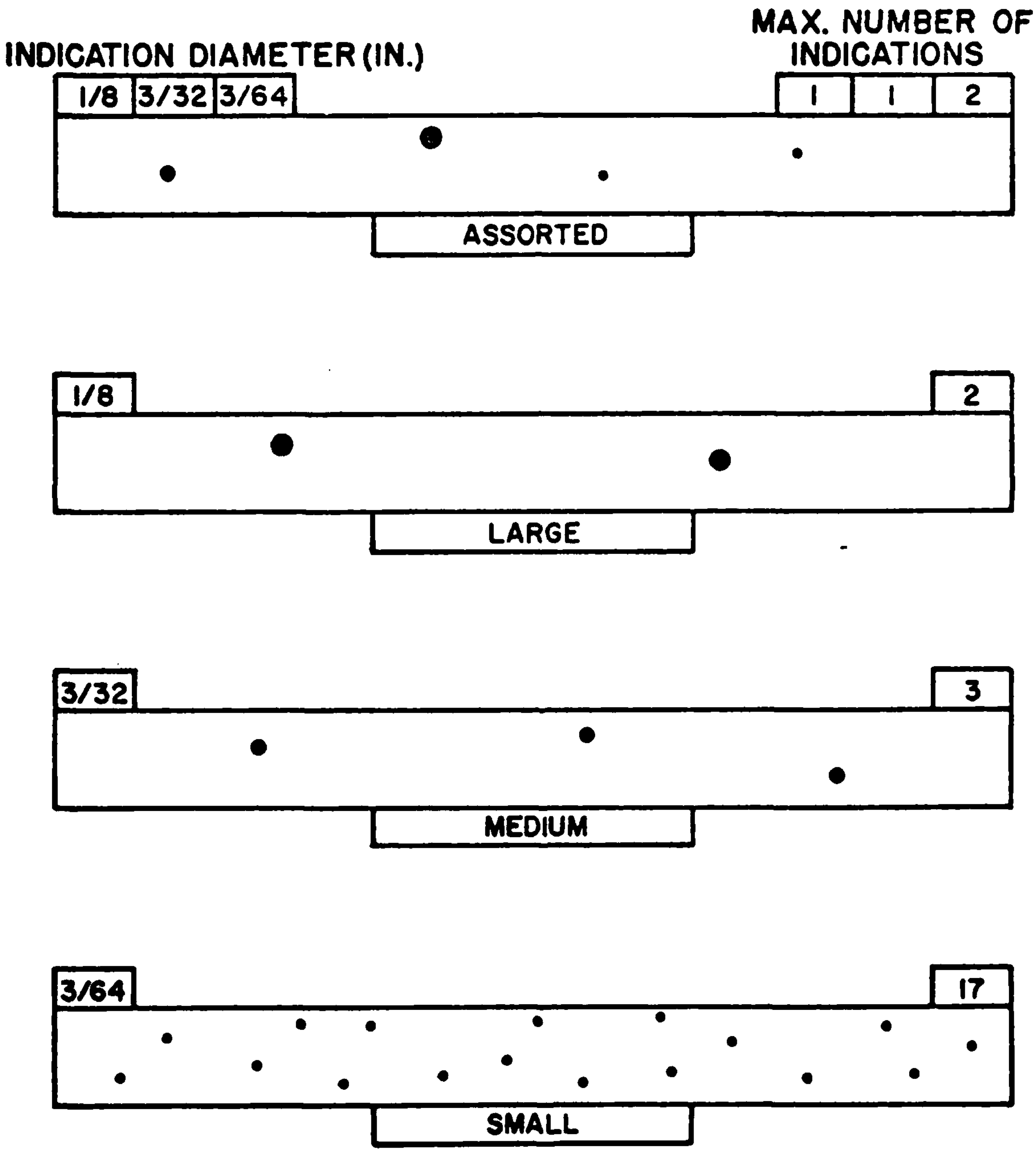


Figure 8-6. Class 3 Weld Surface Inspection Standards for Scattered Rounded or Non-Linear Indications (Sheet 4 of 6).

CLASS 3 WELD

(TOTAL INDICATION AREA = 0.75% OF WELD SURFACE AREA)
FOR MATERIAL THICKNESS = 1/2 INCH

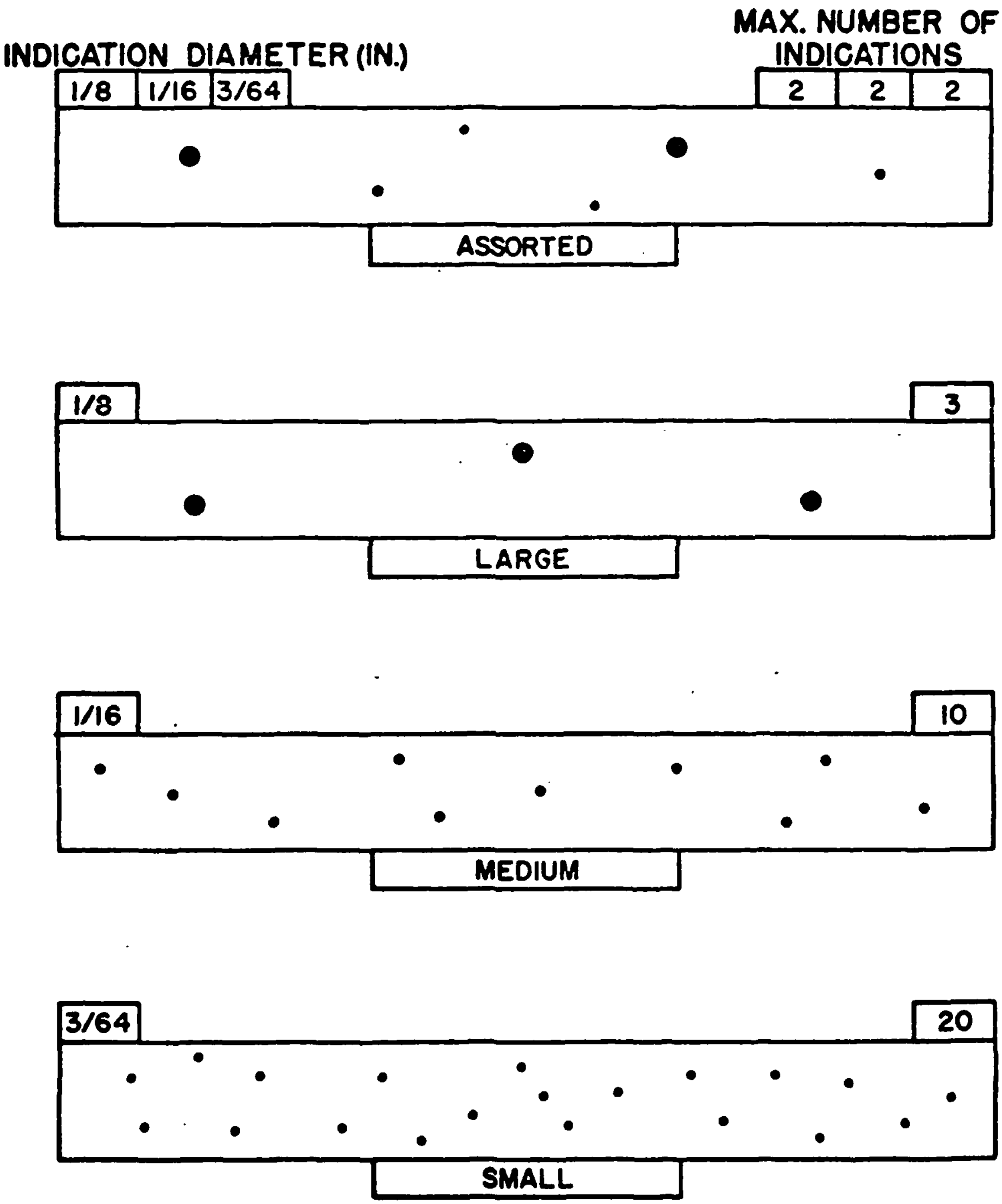


Figure 8-6. Class 3 Weld Surface Inspection Standards for Scattered Rounded or Non-Linear Indications (Sheet 5 of 6).

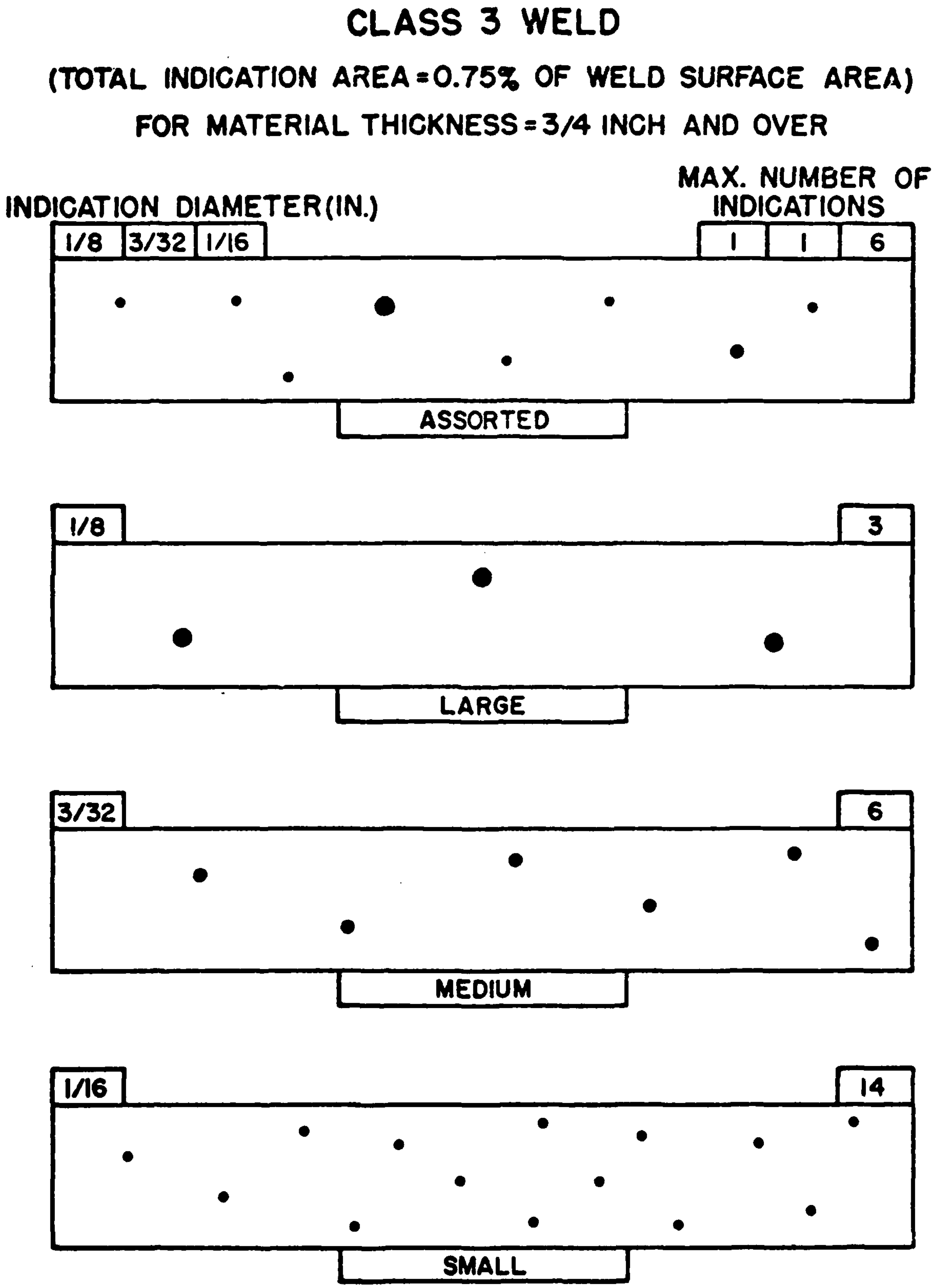


Figure 8-6. Class 3 Weld Surface Inspection Standards for Scattered Rounded or Non-Linear Indications (Sheet 6 of 6).

8.6 RADIOGRAPHIC INSPECTION (RT)

Welds which require radiographic inspection in accordance with Section 6 of this document will meet the applicable acceptance standards contained below. Inadvertent radiographic inspection of welding in the primary hull structure will not be ignored; all radiographs will be considered pertinent and evaluated to acceptance standards.

8.6.1 GENERAL STANDARDS FOR ALL CLASSES

8.6.1.1 Cracks -- Any portion of weld in which radiography indicates the presence of cracks of any type will be identified as discrepant.

8.6.1.2 Melt Thru and Crater Pits--Melt thru and crater pits are acceptable provided the areas do not contain cracks, crevices or globules and provided the weld contour and reinforcement are within the applicable limits specified in this document.

8.6.1.3 Tungsten or Dense Inclusions -- All inclusions of material more dense than the base metal (such as tungsten inclusions) will be considered as porosity. Any portion of weld with a tungsten or dense inclusion having a maximum dimension greater than 20 percent of the weld thickness or 1/8 inch, whichever is less, will be identified as discrepant.

8.6.1.4 Questionable Indications -- Any radiograph which shows questionable indications will be compared with the surface of the weld at the site at which the radiograph was taken to determine whether each indication in question is the result of surface imperfections or sub-surface defects. If the location of the indication cannot be ascertained after visual examination of the site, the indication will be considered sub-surface.

8.6.1.5 Slag, Incomplete Fusion and Incomplete Penetration Indications --

a. General -- Indications having a maximum size of 1/8 inch will be evaluated as porosity. Indications exceeding 1/8-inch in size will be evaluated as specified in this paragraph.

b. Aligned Indications -- A group of radiographic indications of any size will be considered aligned when a straight line through the geometric center of the two outer indications touches the intervening indications and is within the welded seam.

(1) For multiple aligned indications of slag, incomplete fusion or incomplete penetration, any distribution under the limits of the applicable curves of Figure 8-7 is permissible when any and all indications are separated from adjacent indications by at least four (4) times the length of the longer of two adjacent indications.

(2) For multiple aligned indications where the total length of a group of inclusions does not exceed the maximum length permitted for a single indication, there is no restriction on their proximity.

c. Unaligned Indications -- The limits of the applicable curves of Figure 8-7 will govern the quantity and size, but there will be no restriction on distribution, except that any group as defined in Paragraph 8.6.1.5.b(2) above and any other permissible individual indications will be separated in any direction from adjacent groups or individual indications. The minimum acceptable separation will be the lesser of L or 1/2 inch where L is the length of the longer of the two adjacent indications.

8.6.1.6 Porosity --

a. General -- Porosity indications 1/64 inch or less in diameter will be acceptable.

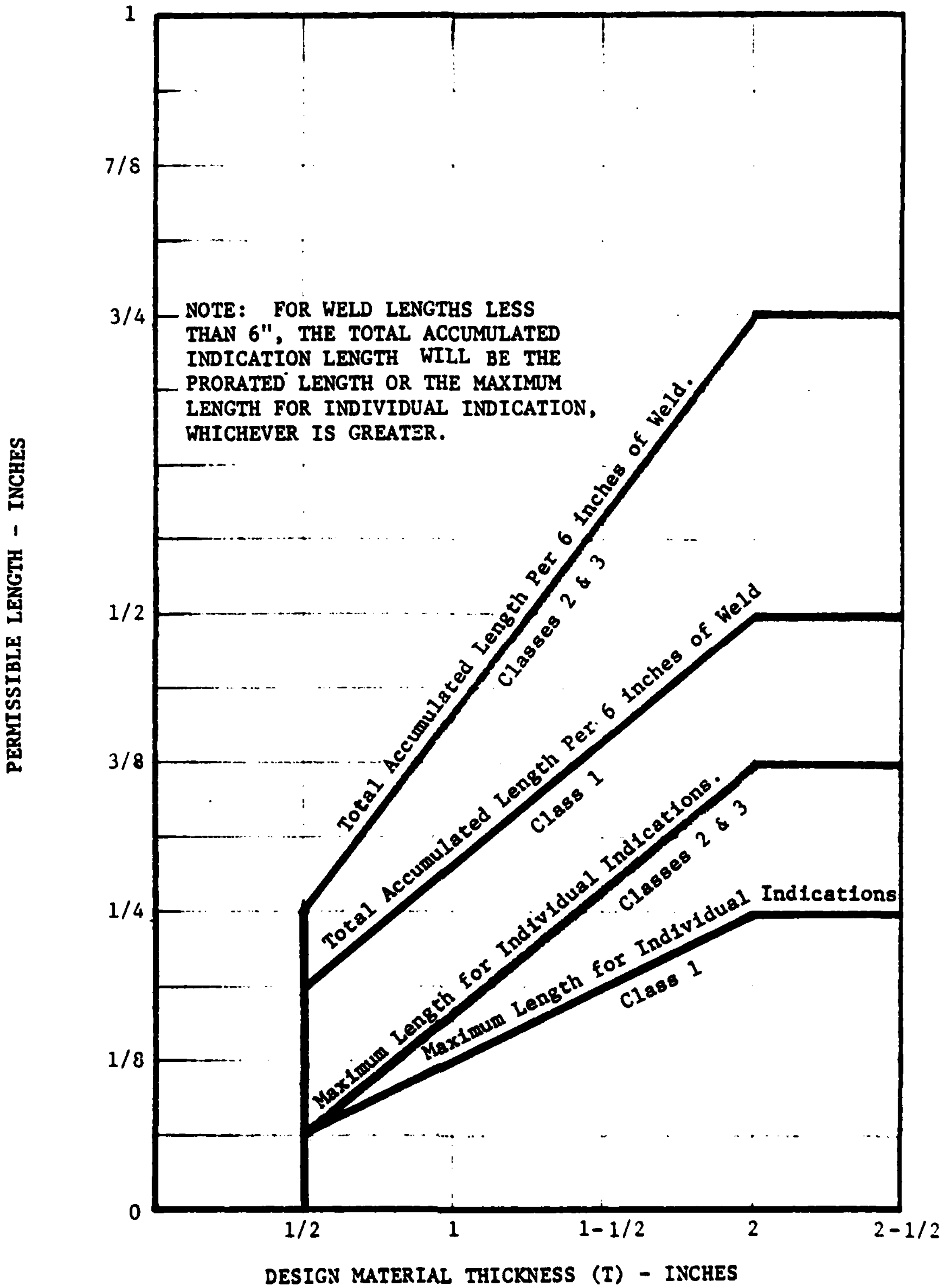


Figure 8-7. Radiographic Acceptance Standards for Slag, Incomplete Fusion and Incomplete Penetration Indications.

b. Randomly Dispersed Porosity --

(1) Class Standards for Aluminum -- Pictorial presentation of randomly dispersed porosity for welds in various thicknesses of aluminum base metal are shown in Figure 8-8 for both Class 1 and Class 2 acceptance standards and in Figure 8-9 for Class 3 acceptance standards. The porosity patterns shown are illustrative of particular combinations of number and size of indications permitted. For weld lengths less than 6 inches, or weld widths less than shown, the acceptance criteria will be proportionally reduced. Increasing the allowable pores to compensate for weld widths greater than that shown in Figures 8-8 and 8-9 will not be permitted. When randomly distributed indications occur in a concentrated pattern, but not to such a degree as to be classed as rejectable clusters, these will be rejectable when the concentration in any one inch or more of weld length equals or exceeds twice the amount shown in the applicable Figure 8-8 or 8-9 chart.

c. Aligned Porosity -- Four or more pores linearly aligned such that the distance between any two adjacent pores is less than D or 1/16 inch, whichever is greater (where D is the larger of two adjacent pores) will be identified as discrepant. However, such linearly aligned pores will be acceptable when the total length of the line of pores does not exceed the length permitted for single incomplete fusion and incomplete penetration indications under the applicable class standard of Figure 8-7.

d. Clustered Porosity -- Porosity will be classed as clustered when a group of four or more indications are concentrated in a manner as shown in Figure 8-10. Sporadic pores separated from the group by 1/8 inch or 3D, (where D is the diameter of

CLASS 1 AND CLASS 2 WELDS
FOR BASE MATERIAL THICKNESSES LESS THAN 0.250 INCH

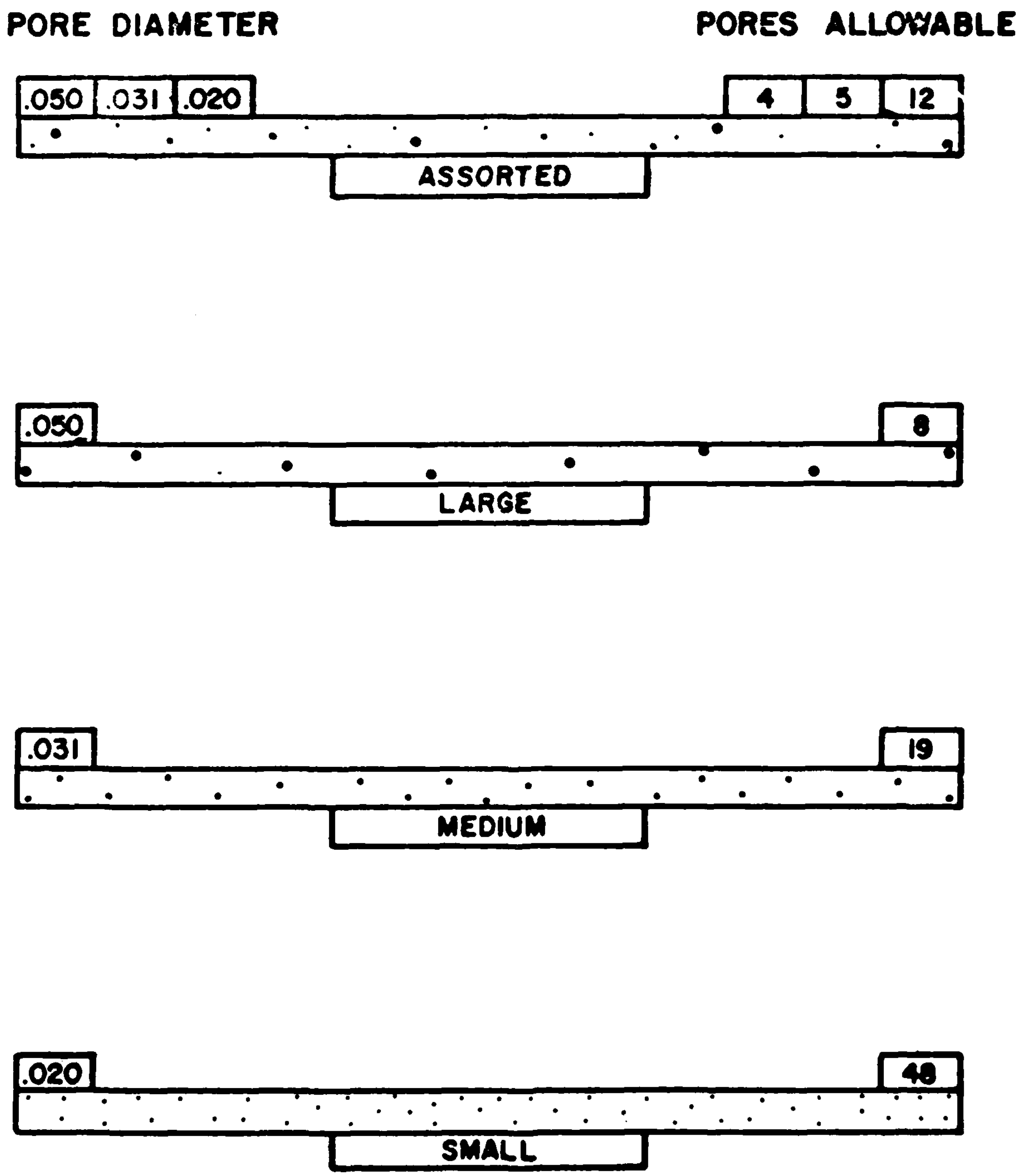


Figure 8-8. Classes 1 and 2 Weld Radiographic Inspection Standards for Randomly Dispersed Porosity (Sheet 1 of 7).

CLASS 1 AND CLASS 2 WELDS
FOR BASE MATERIAL THICKNESSES FROM 0.250 THRU 0.374 INCH

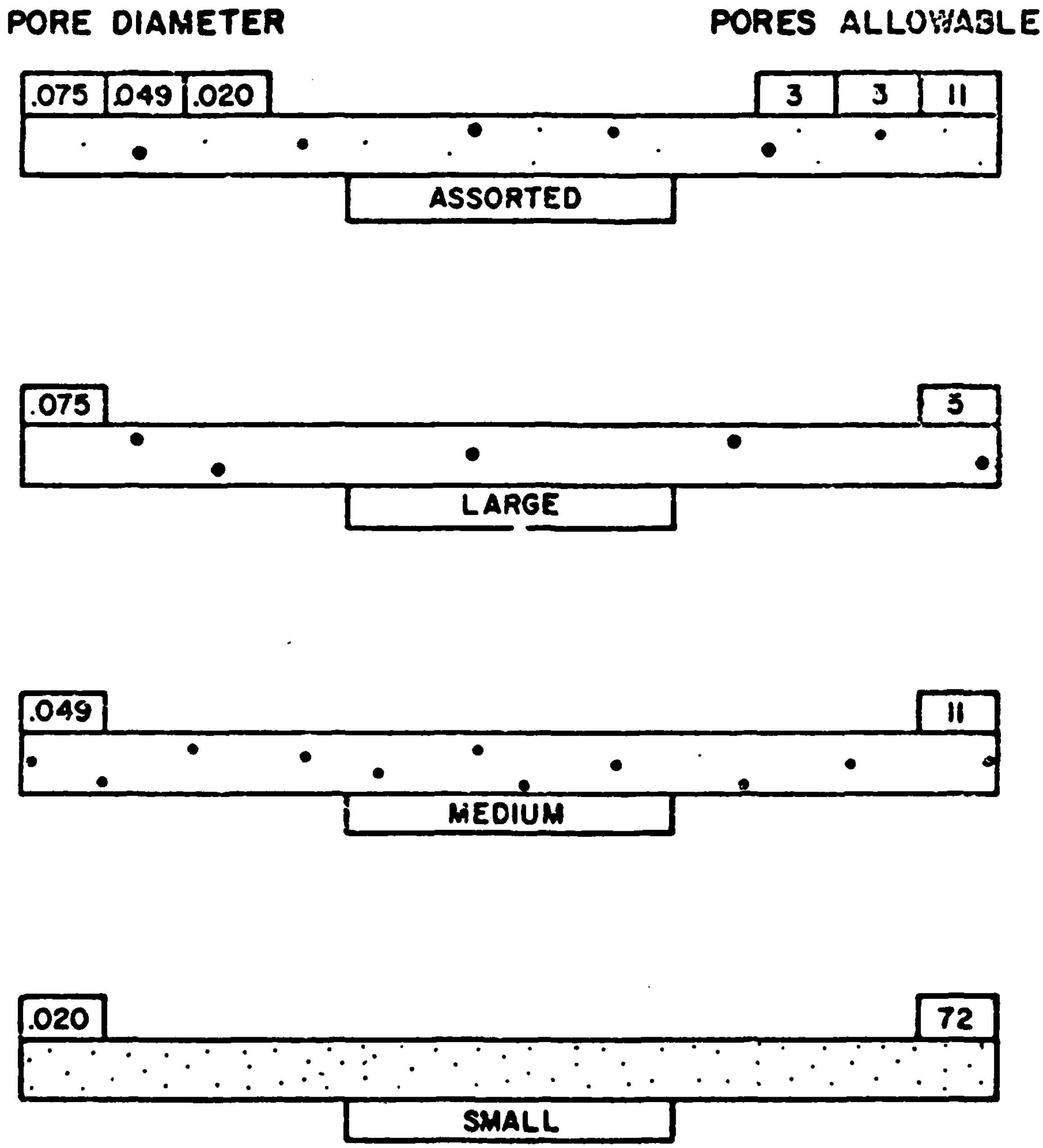


Figure 8-8. Classes 1 and 2 Weld Radiographic Inspection Standards for Randomly Dispersed Porosity (Sheet 2 of 7).

CLASS 1 AND CLASS 2 WELDS
FOR BASE MATERIAL THICKNESSES FROM 0.375 THRU 0.500 INCH

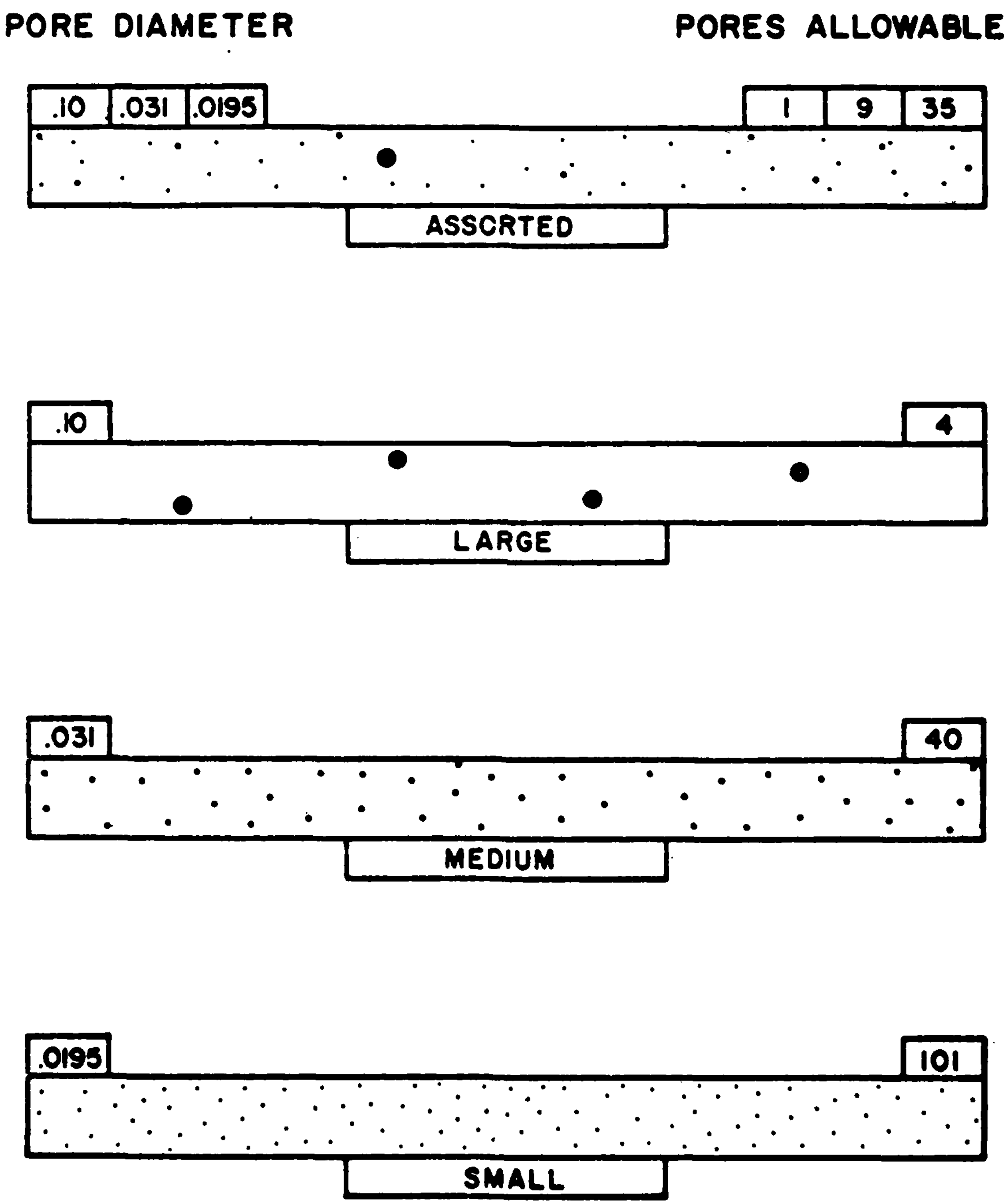


Figure 8-8. Classes 1 and 2 Weld Radiographic Inspection Standards for Randomly Dispersed Porosity (Sheet 3 of 7).

CLASS 1 AND CLASS 2 WELDS
FOR BASE MATERIAL THICKNESSES FROM 0.501 THRU 0.750 INCH

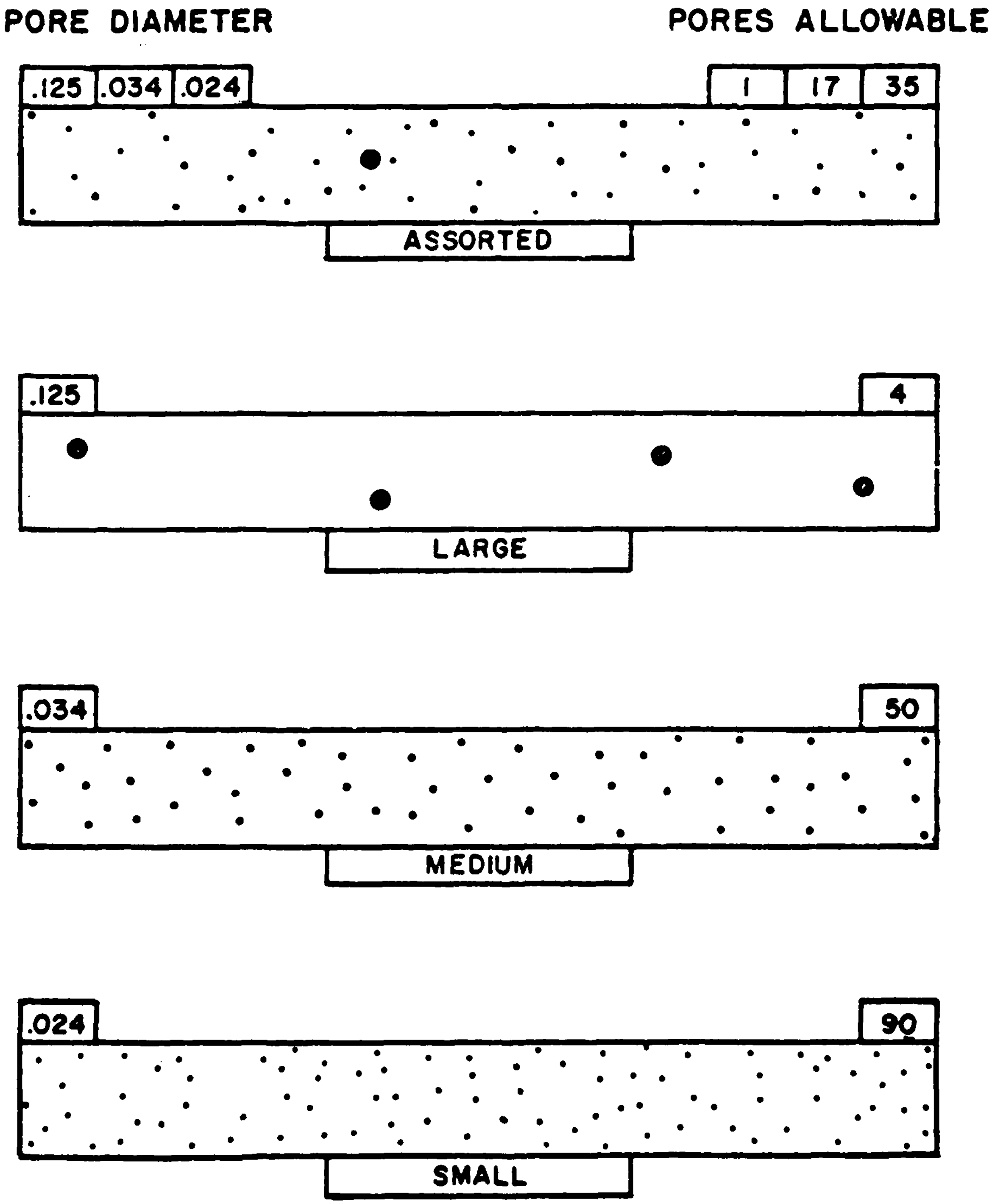


Figure 8-8. Classes 1 and 2 Weld Radiographic Inspection Standards for Randomly Dispersed Porosity (Sheet 4 of 7).

CLASS 1 AND CLASS 2 WELDS
FOR BASE MATERIAL THICKNESSES FROM 0.751 THRU 1.000 INCH

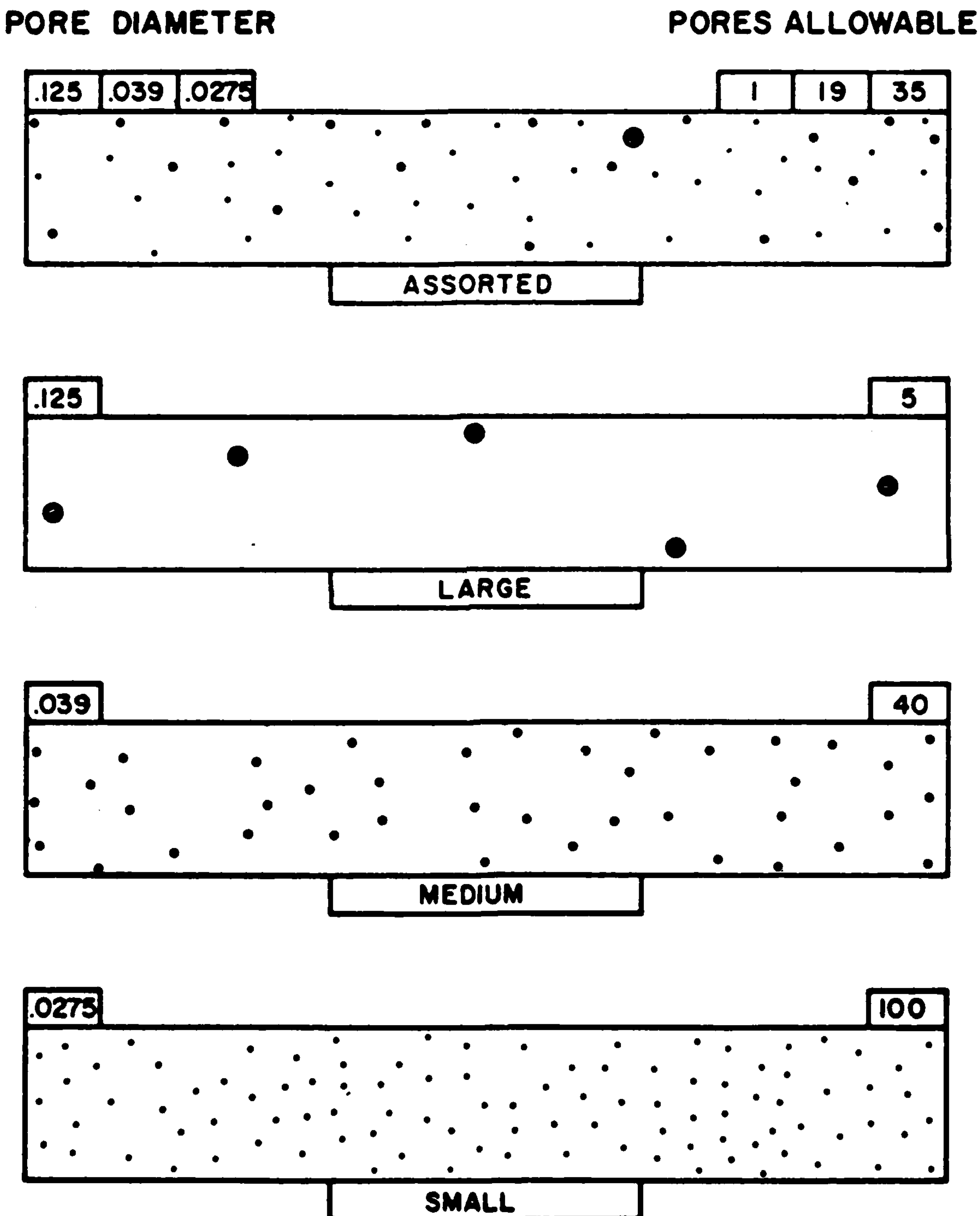


Figure 8-8. Classes 1 and 2 Weld Radiographic Inspection Standards for Randomly Dispersed Porosity (Sheet 5 of 7).

CLASS 1 AND CLASS 2 WELDS
FOR BASE MATERIAL THICKNESSES FROM 1.001 THRU 1.500 INCH

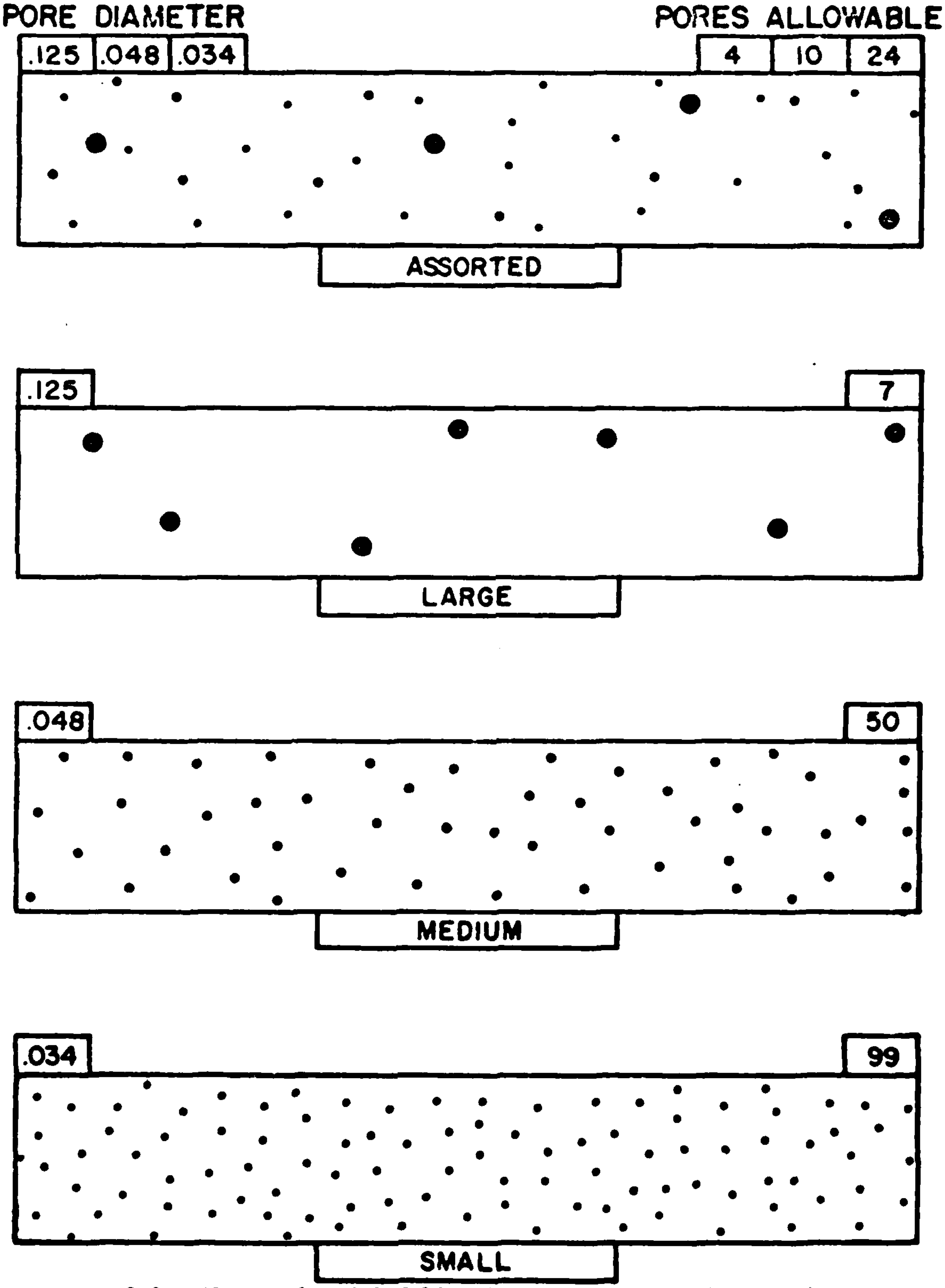


Figure 8-8. Classes 1 and 2 Weld Radiographic Inspection Standards for Randomly Dispersed Porosity (Sheet 6 of 7).

CLASS 1 AND CLASS 2 WELDS
FOR BASE MATERIAL THICKNESSES FROM 1.501 THRU 2.000 INCH

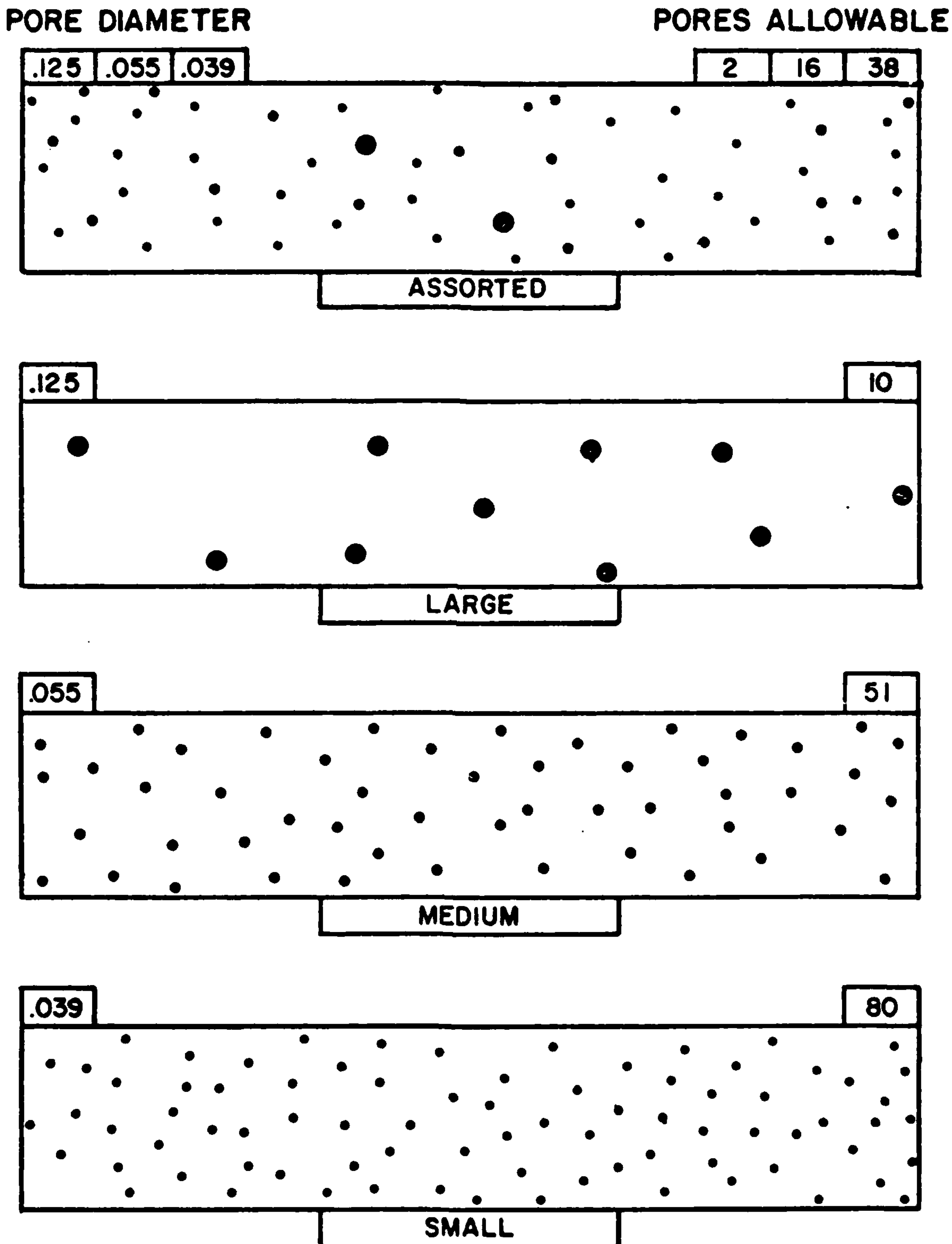


Figure 8-8. Classes 1 and 2 Weld Radiographic Inspection Standards for Randomly Dispersed Porosity (Sheet 7 of 7).

CLASS 3 WELD
FOR BASE MATERIAL THICKNESS LESS THAN 0.250 INCH

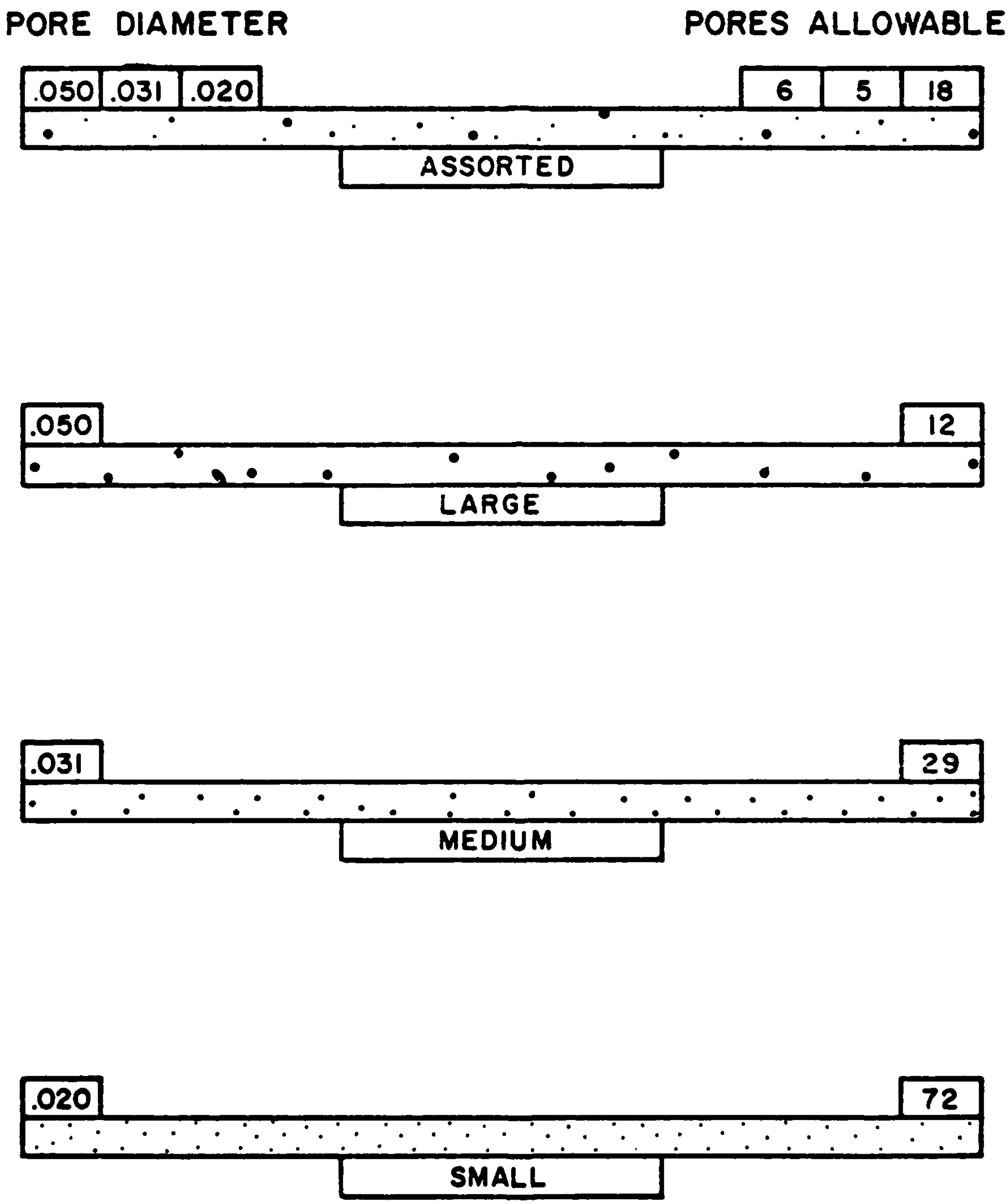


Figure 8-9. Class 3 Weld Radiographic Inspection Standards for Randomly Dispersed Porosity (Sheet 1 of 7).

CLASS 3 WELD
FOR BASE MATERIAL THICKNESSES FROM 0.250 THRU 0.374 INCH

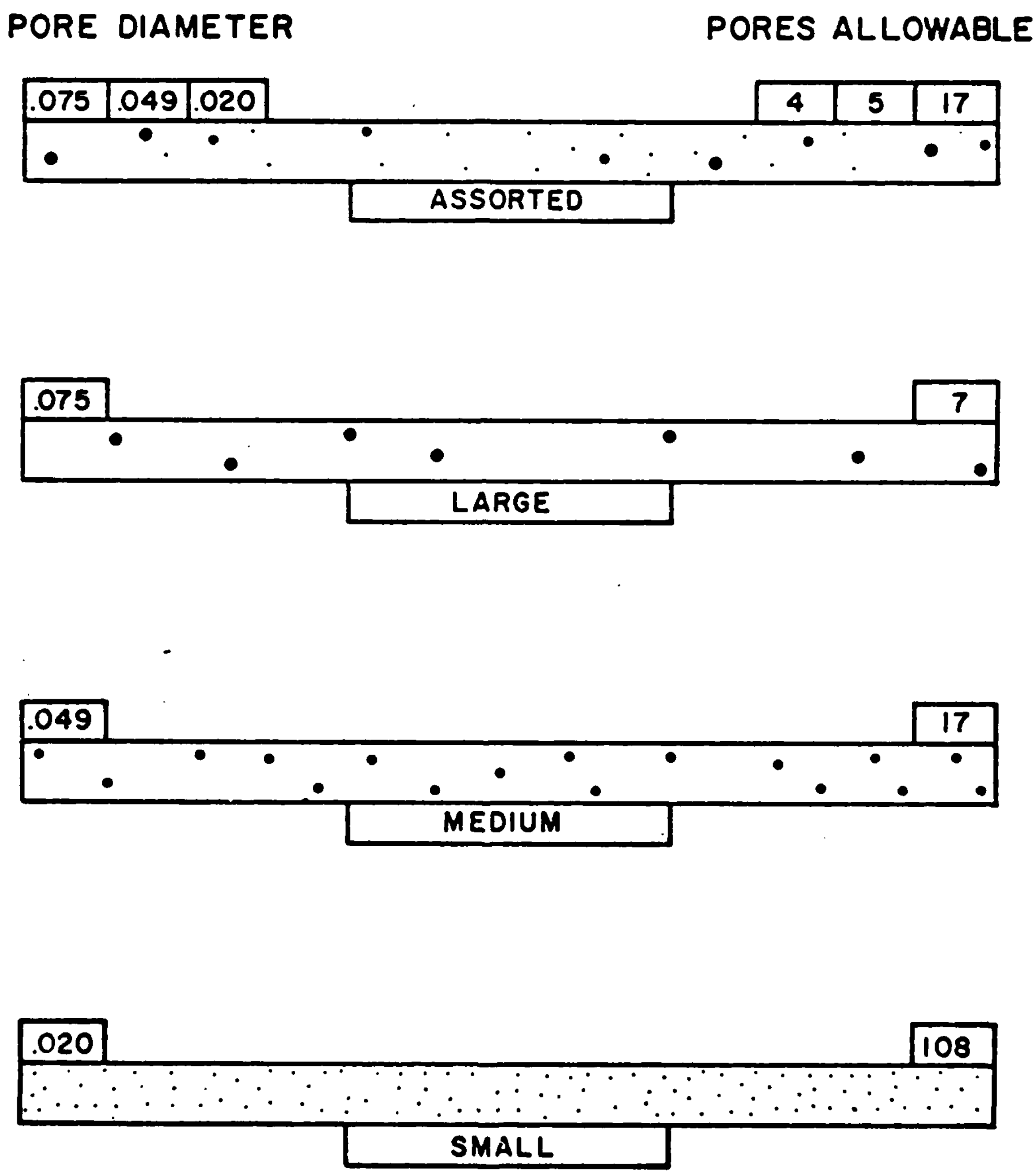


Figure 8-9. Class 3 Weld Radiographic Inspection Standards for Randomly Dispersed Porosity (Sheet 2 of 7).

CLASS 3 WELD
FOR BASE MATERIAL THICKNESSES FROM 0.375 THRU 0.500 INCH

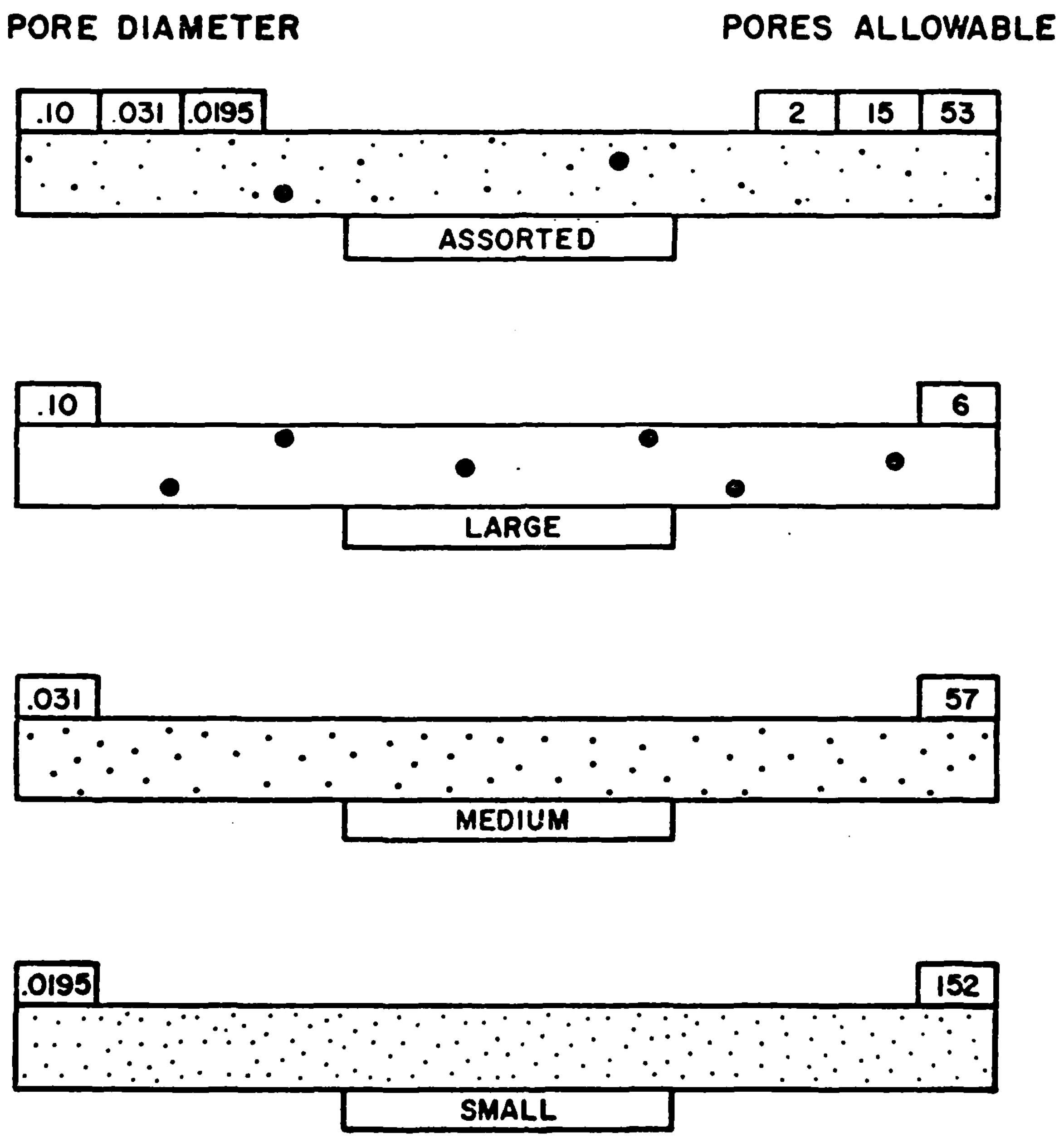


Figure 8-9. Class 3 Weld Radiographic Inspection Standards for Randomly Dispersed Porosity (Sheet 3 of 7).

CLASS 3 WELD
FOR BASE MATERIAL THICKNESSES FROM 0.501 THRU 0.750 INCH

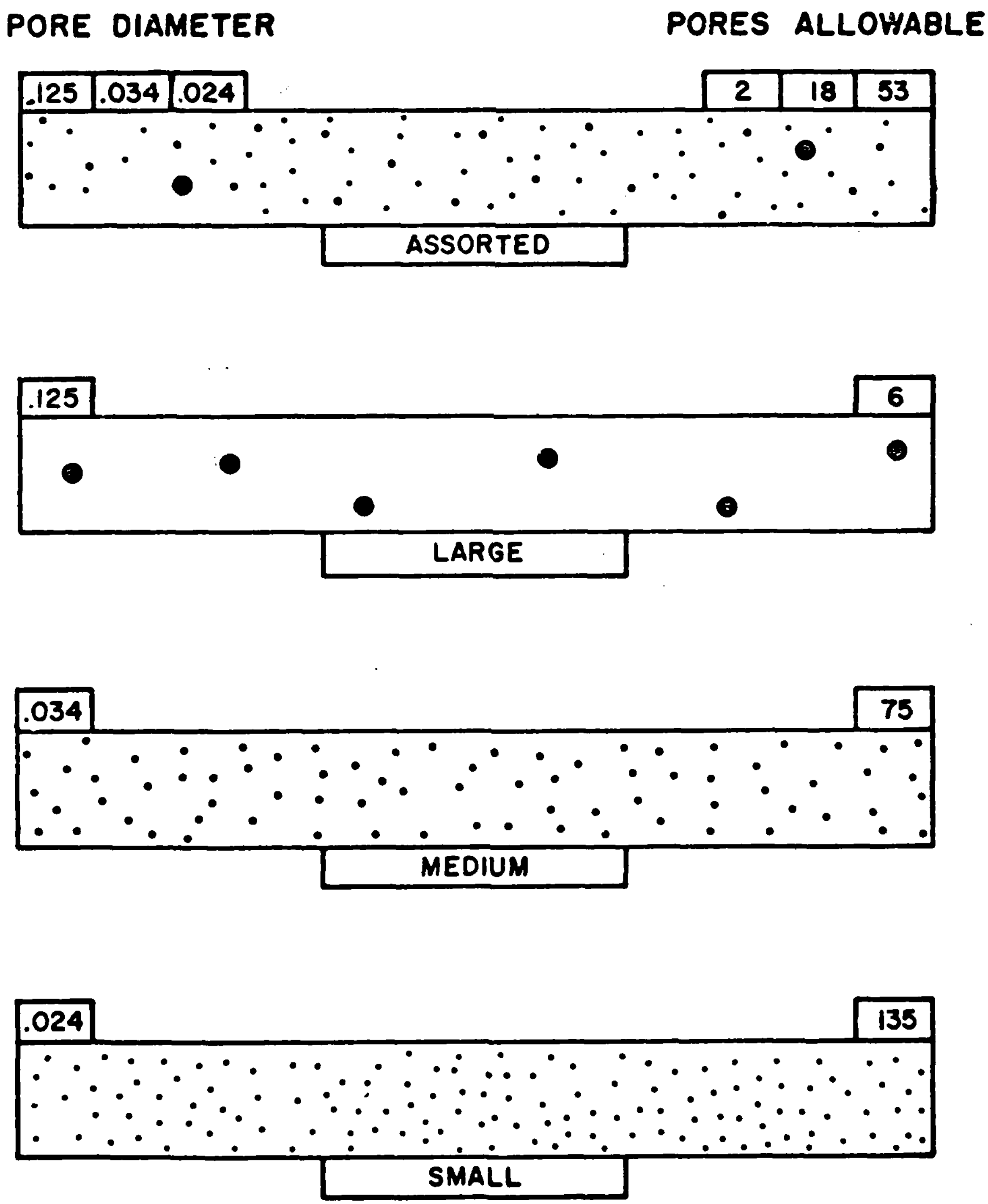


Figure 8-9. Class 3 Weld Radiographic Inspection Standards for Randomly Dispersed Porosity (Sheet 4 of 7).

CLASS 3 WELD
FOR BASE MATERIAL THICKNESSES FROM 0.751 THRU 1.000 INCH

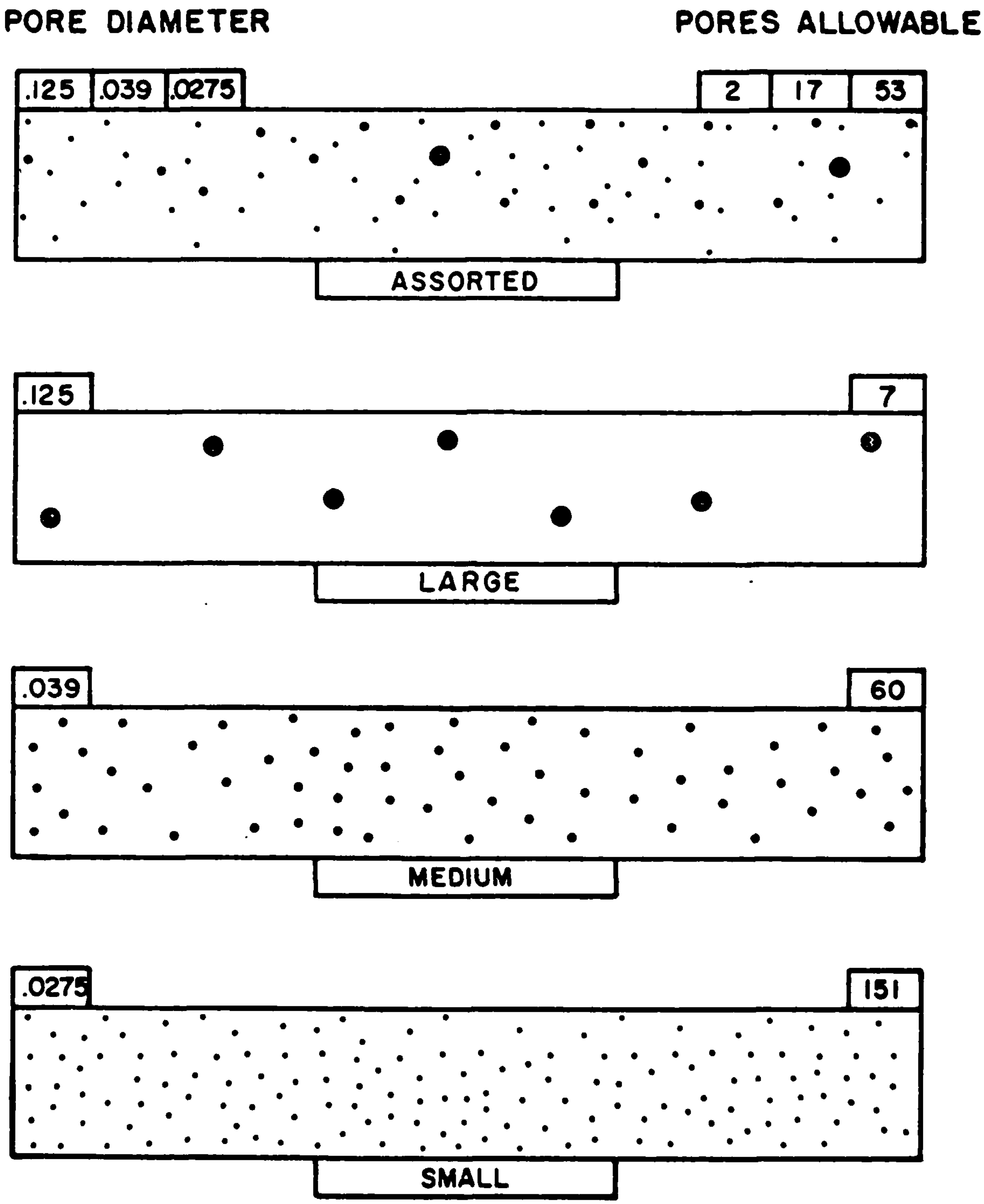


Figure 8-9. Class 3 Weld Radiographic Inspection Standards for Randomly Dispersed Porosity (Sheet 5 of 7).

CLASS 3 WELD
FOR BASE MATERIAL THICKNESSES FROM 1.001 THRU 1.500 INCH

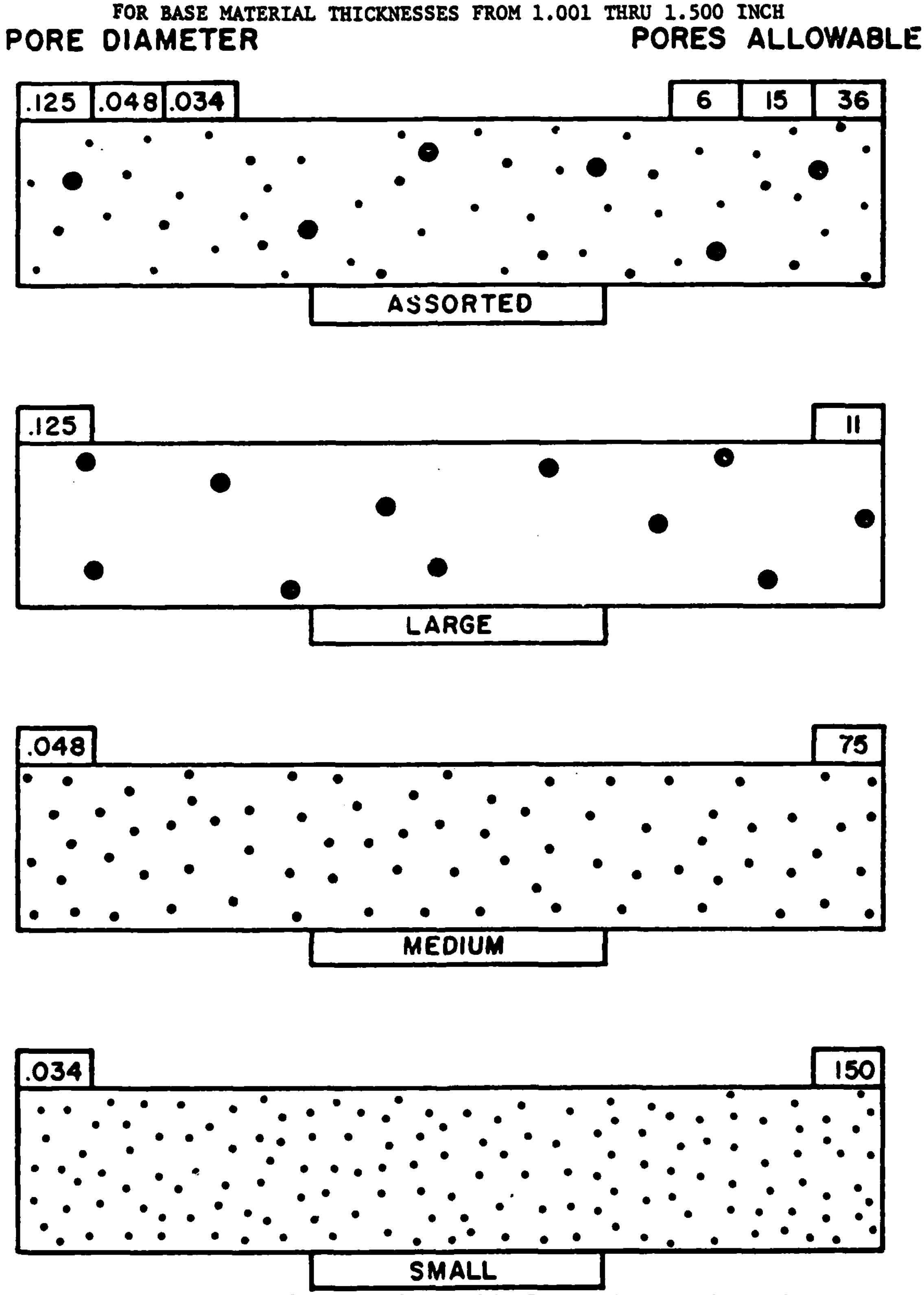


Figure 8-9. Class 3 Weld Radiographic Inspection Standards for Randomly Dispersed Porosity (Sheet 6 of 7).

TPP002B

CLASS 3 WELD
FOR BASE MATERIAL THICKNESSES FROM 1.501 THRU 2.000 INCH

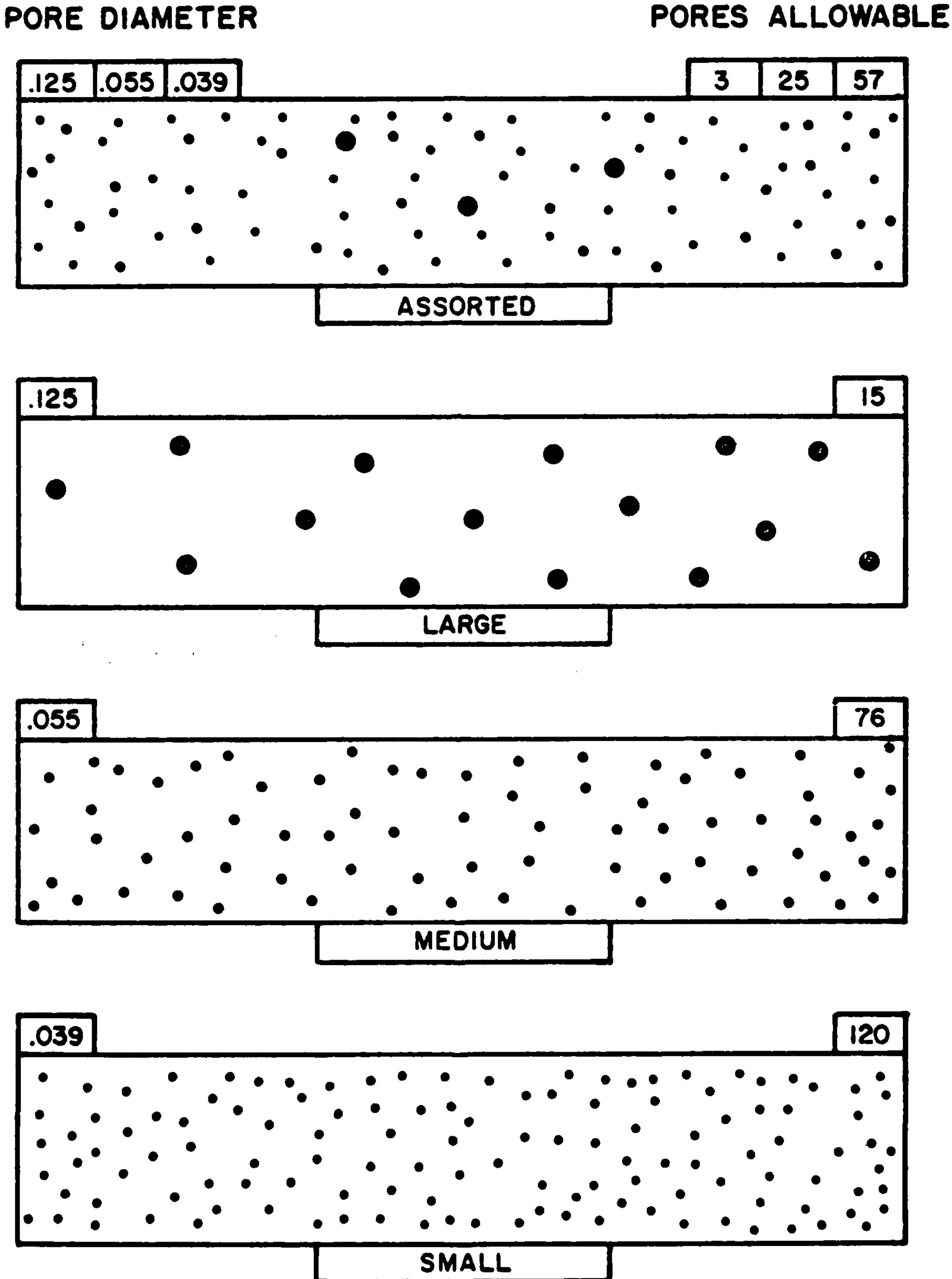
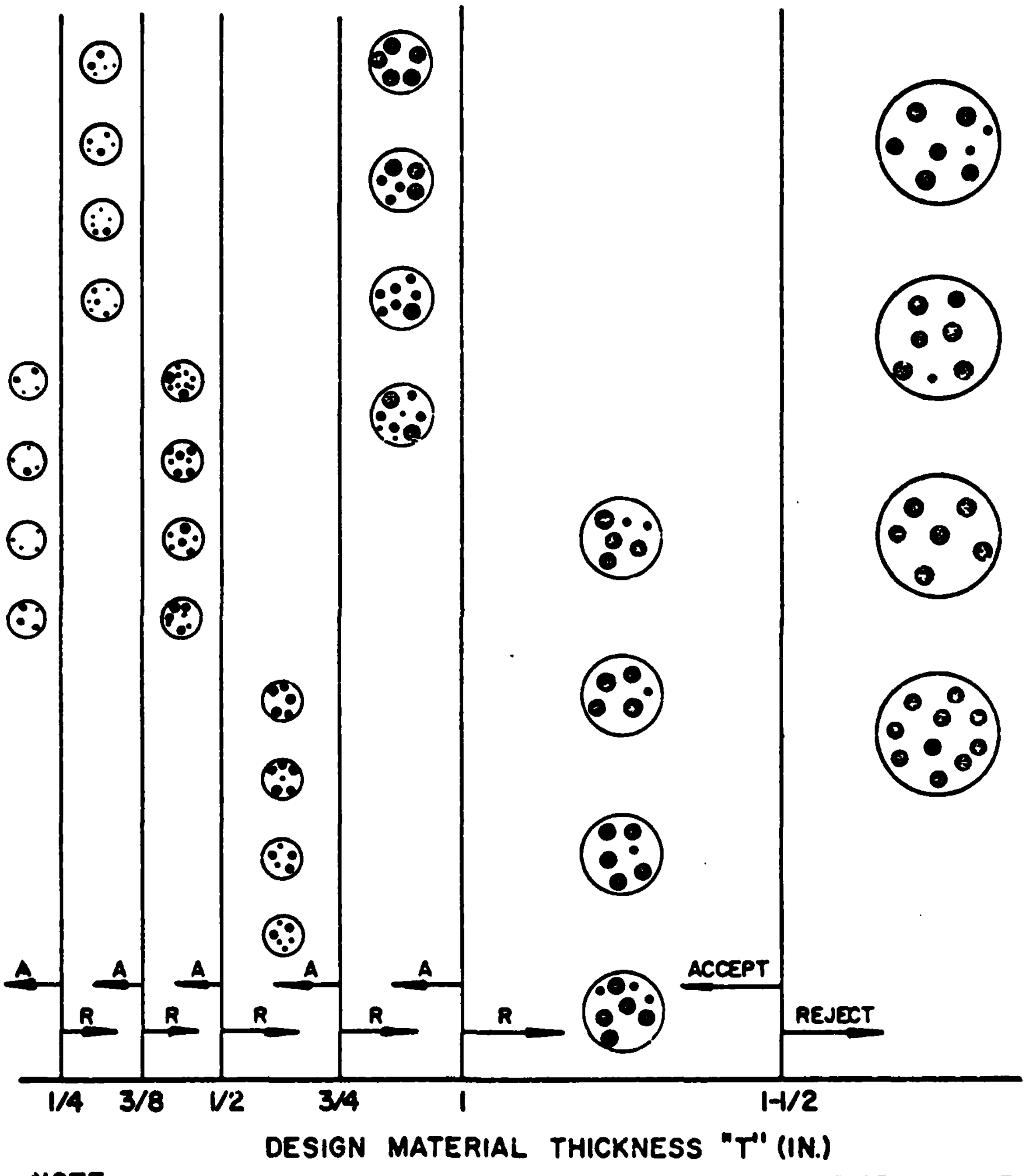


Figure 8-9. Class 3 Weld Radiographic Inspection Standards for Randomly Dispersed Porosity (Sheet 7 of 7).



NOTE: ILLUSTRATION OF CLUSTERED POROSITY FOR VARIOUS THICKNESSES. ACCEPT ALL TO THE LEFT OF ANY VERTICAL THICKNESS LINE, AND REJECT ALL TO THE RIGHT.

Figure 8-10. Radiographic Standards for Clustered Porosity.

the largest pore in that group) whichever is greater, will not be considered a part of the group.

e. Tailed Porosity -- One-ended tailed porosity will be treated as unaligned indication. Porosity with tails on both ends will be treated as an aligned indication. Sharp ended tailed porosity with a length-to-width ratio of 5 or greater will be treated as a crack in critical structures as defined in paragraph 6.3 of this document.

8.6.1.7 Oxidation of Root -- Oxidation of the root indicated by a wrinkled or "sugared" appearance on the radiograph will be identified as discrepant.

8.6.1.8 Multiple Indications -- The presence of more than one type of indication on the same radiograph is permitted provided each indication type is within the limits specified.

8.6.2 CLASS 1 RADIOGRAPHIC ACCEPTANCE STANDARDS

8.6.2.1 General -- The provision of paragraph 8.6.1 above will apply where applicable.

8.6.2.2 Incomplete Fusion and Incomplete Penetration -- Welds will be free of incomplete fusion and incomplete penetration indications which exceed the limits for Class 1 in Figure 8-7.

8.6.2.3 Randomly Dispersed Porosity -- Indications which exceed the limits of Figure 8-8, proportionately modified (if required) as described above in paragraph 8.6.1.6.b(1), will be identified as discrepant.

8.6.2.4 Clustered Porosity -- The acceptance standard for clustered porosity will be as follows:

Base Metal Thickness "T"	Maximum Cluster Diameter	Maximum Number of Pores
0.250 inch and less	1/4 inch	4, any size
0.251 thru 0.500 inch	1/4 inch	No limit, except summation of pore diameters will not exceed 1/4 in.
0.501 inch and greater	1/2 T or 3/4 inch whichever is less	No limit, except summation of pore diameters will not exceed 1/2 T or 3/4 in., whichever is less

In addition, the minimum separation between clusters will be 4T or 3 inches, whichever is less.

8.6.2.5 Maximum Pore Diameter -- The maximum acceptable pore diameter, except for isolated pores in material 5/16 inch and greater in thickness, will be the largest diameter specified in Figure 8-8 for the applicable base material thickness (T). In materials 5/16 inch or greater in thickness, isolated pores which exceed the largest size specified for the applicable thickness range are permissible provided such pores do not exceed the lesser of 25 percent of T or 3/16 inch, and that there is not more than one such pore in any 6-inch length of weld.

8.6.2.6 Undercut -- Where visual inspection is not feasible, the acceptability of undercut which is detected by radiography will be determined by comparison with a radiograph of an identical reference sample joint containing the maximum undercut acceptable per paragraph 8.4.2.2 above.

8.6.3 CLASS 2 RADIOGRAPHIC ACCEPTANCE STANDARDS

8.6.3.1 General -- The provisions of paragraph 8.6.1 above will apply where applicable.

8.6.3.2 Incomplete Fusion and Incomplete Penetration -- Welds will be free of incomplete fusion and incomplete penetration indications which exceed the limits for Class 2 in Figure 8-7.

8.6.3.3 Randomly Dispersed Porosity -- Indications which exceed the limits of Figure 8-8, proportionately modified (if required) as described above in paragraph 8.6.1.6.b(1), will be identified as discrepant.

8.6.3.4 Clustered Porosity -- The acceptance criteria of paragraph 8.6.2.4 above will apply.

8.6.3.5 Maximum Pore Diameter -- The maximum pore diameter will be as specified above in paragraph 8.6.2.5.

8.6.3.6 Undercut -- Where visual inspection is not feasible, the acceptability of undercut which is detected by radiography will be determined by comparison with a radiograph of an identical reference sample joint containing the maximum undercut acceptable per paragraph 8.4.3.2 above.

8.6.4 Class 3 RADIOGRAPHIC ACCEPTANCE STANDARDS

8.6.4.1 General -- The provisions of paragraph 8.6.1 above will apply where applicable.

8.6.4.2 Incomplete Fusion and Incomplete Penetration -- Welds will be free of incomplete fusion and incomplete penetration which exceed the limits for Class 3 in Figure 8-7.

8.6.4.3 Randomly Dispersed Porosity -- Indications which exceed the limits of Figure 8-9, proportionately modified (if required) as described above in paragraph 8.6.1.6.b(1), will be identified as discrepant.

8.6.4.4 Clustered Porosity -- Clustered or concentrated porosity indications are acceptable provided these indications, when evaluated with other porosity indications, do not exceed the maximum number and size shown in the applicable randomly dispersed porosity chart of Figure 8-9 in any 6-inch length of weld.

8.6.4.5 Maximum Pore Diameter -- The maximum pore diameter will be as specified in paragraph 8.6.2.5 above.

8.6.4.6 Undercut -- The requirements of paragraph 8.6.3.6 above will be applicable.

8.6.5 POST WELD REPAIR RADIOGRAPHY -- Discontinuities in the weld metal identified by radiography after repairs are made will be evaluated to the same standards applied to the original weld.

8.7 ULTRASONIC INSPECTION (UT)

Welds which are evaluated using ultrasonic inspection will meet the applicable acceptance standards contained below. Acceptance criteria for production tee welds and for full penetration production butt and corner welds are included. The applicable acceptance class will be as specified above in paragraph 8.3.

8.7.1 GENERAL

8.7.1.1 System Requirements -- The ultrasonic inspection system, including personnel, procedures and equipment employed in the evaluation of discontinuities will comply with the requirements of paragraph 7.6 of this document.

8.7.1.2 Signal Amplitude -- The signal amplitude to be utilized for acceptance or rejection of any discontinuity will be the peak amplitude obtained as the transducer or search unit is moved along the length of the discontinuity.

8.7.1.3 Discrepant Discontinuities -- Only those discontinuities which are identified as discrepant need to be removed and repaired as necessary to render the weld equivalent to, or better than, the applicable standards.

8.7.2 CLASS 1 ULTRASONIC ACCEPTANCE STANDARDS

8.7.2.1 Full Penetration Butt Welds and Corner Welds --

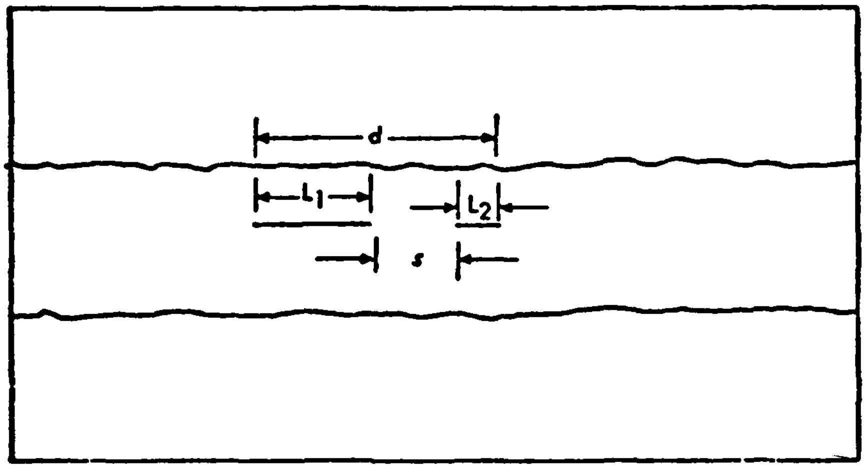
a. Any discontinuity whose reflection exceeds the Amplitude Reject Level (ARL) will be identified as discrepant.

b. Any discontinuity whose reflection is less than the Disregard Level (DRL) will be acceptable.

c. Discontinuities whose reflections are equal to or greater than the DRL, up to and including the ARL, will be evaluated as follows:

(1) If the discontinuity length exceeds 1/2 the thickness of the thinner member, it will be identified as discrepant. In no case will any single discontinuity length exceed 1-1/2 inches.

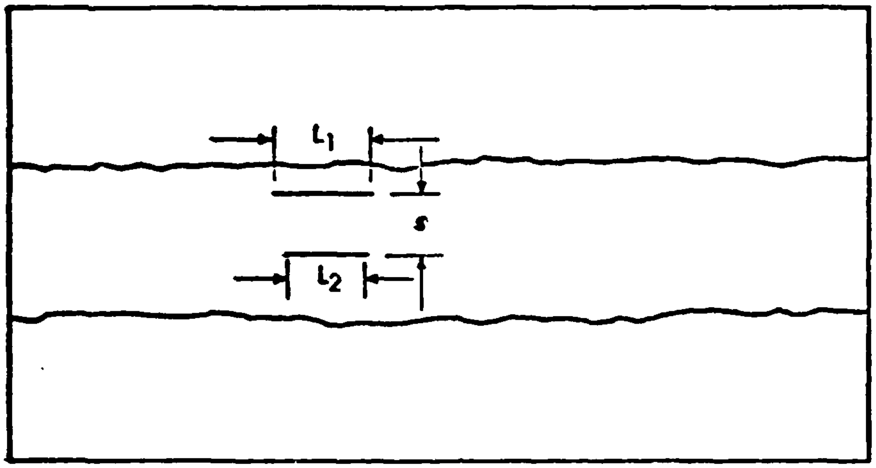
(2) Adjacent discontinuities separated by less than 2 L of sound metal (L = Length of longest discontinuity) will be considered as a single discontinuity. The maximum distance between the outer extremities of any two such discontinuities or the sum of their lengths, whichever is greater, will not exceed the length specified in (1) above. (See Figure 8-11.)



TOP VIEW

CODE	DATA
L = LENGTH OF DISCONTINUITY	L_1 = 3/4 INCH
s = MAXIMUM SPACING BETWEEN ADJACENT DISCONTINUITIES	L_2 = 1/4 INCH
d = MAXIMUM DISTANCE BETWEEN OUTER EXTREMITIES	s = 1/2" (LESS THAN $2L_1$)
	EVALUATION IS BASED ON D OR
	$L_1 + L_2 + s$

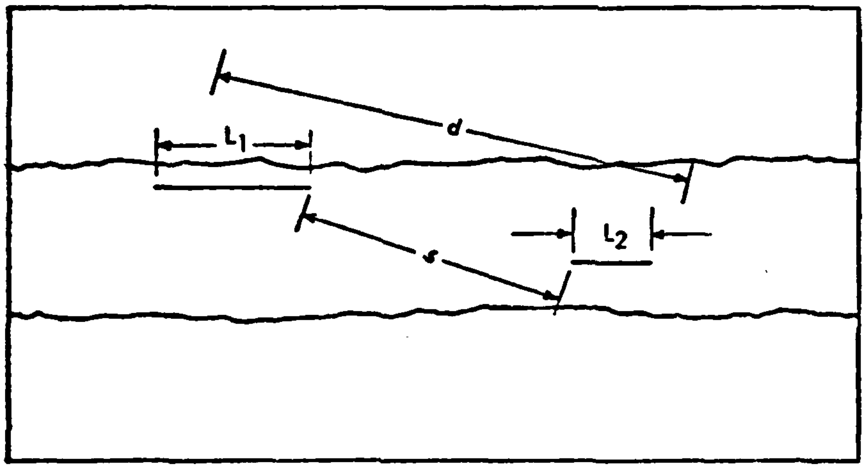
Figure 8-11. Evaluation of Adjacent Discontinuities (Sheet 1 of 4).



TOP VIEW

DATA	CODE
L = LENGTH OF DISCONTINUITY	L_1 = 5/8 INCH
s = MAXIMUM SPACING BETWEEN ADJACENT DISCONTINUITIES	L_2 = 1/2 INCH
	s = 3/8 INCH (LESS THAN $2L_1$)
	EVALUATION IS BASED ON
	$L_1 + L_2$

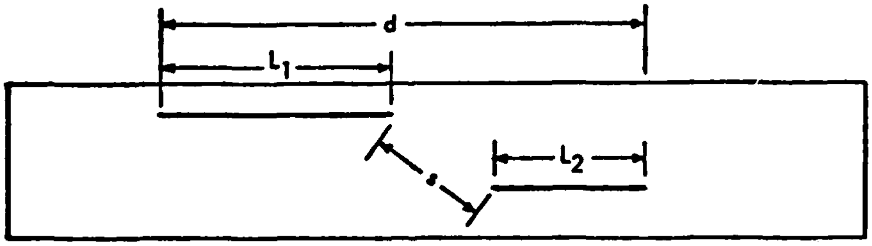
Figure 8-11. Evaluation of Adjacent Discontinuties (Sheet 2 of 4).



TOP VIEW

CODE	DATA
L = LENGTH OF DISCONTINUITY	L_1 = 1 INCH
s = MAXIMUM SPACING BETWEEN ADJACENT DISCONTINUITIES	L_2 = 1/2 INCH
d = MAXIMUM DISTANCE BETWEEN OUTER EXTREMITIES	s = 1-3/4 INCH
	EVALUATION IS BASED ON
	$L_1 + L_2 + s$

Figure 8-11. Evaluation of Adjacent Discontinuities (Sheet 3 of 4).



SIDE VIEW (CROSS SECTION)

CODE

L = LENGTH OF DISCONTINUITY

s = MAXIMUM SPACING BETWEEN ADJACENT DISCONTINUITIES

d = MAXIMUM DISTANCE BETWEEN OUTER EXTREMITIES

DATA

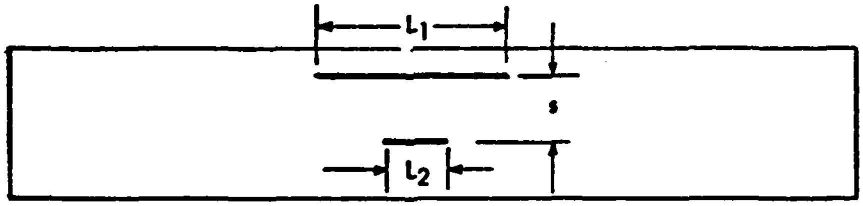
L_1 = 1-1/2 INCH

L_2 = 1 inch

s = 3/4 INCH

EVALUATION IS BASED ON d or

$L_1 + L_2 + s$



SIDE VIEW (CROSS SECTION)

CODE

L = LENGTH OF DISCONTINUITY

s = MAXIMUM SPACING BETWEEN ADJACENT DISCONTINUITIES

DATA

L_1 = 1-1/4 INCH

L_2 = 3/8 INCH

s = 1/2 INCH (LESS THAN $2L_1$)

Figure 8-11. Evaluation of Adjacent Discontinuties (Sheet 4 of 4)

(3) If the total accumulative length of discontinuities in any 12 inches of weld length exceeds the thickness of the thinner member, that weld length will be identified as discrepant.

8.7.2.2 Full Penetration Tee Joints for Incomplete Root Penetration -- Acceptance criteria for incomplete root penetrations of full penetration tee joints will be as follows:

a. Any discontinuity whose reflection exceeds the ARL will be identified as discrepant.

b. Any discontinuity whose reflection is less than the DRL will be acceptable.

c. Any discontinuity whose reflection is equal to or greater than the DRL, up to an including the ARL, will be identified as discrepant if its length exceeds 6 inches.

d. If the total accumulative length of the discontinuities in any 12 inches of weld length exceeds 6 inches, the weld length will be identified as discrepant.

8.7.2.3 Partial and Full Penetration Tee Joints for Weld Depth -- The depth of weld penetration and reinforcement (weld cross-section width at the through member surface) will be as specified on the applicable drawings.

8.7.2.4 Tee Joint Weld Discontinuities into the Through Member --

(a) Any discontinuity whose reflection exceeds the ARL will be identified as discrepant.

(b) Any discontinuity whose reflection is below the DRL will be acceptable.

(c) Discontinuities whose reflections are equal to or greater than the DRL, up to an including ARL, will be identified as discrepant if the dimension into the plate is 1/16 inch or greater.

8.7.3 CLASS 2 ULTRASONIC ACCEPTANCE STANDARDS

8.7.3.1 Full Penetration Butt Welds and Corner Welds --

a. Any discontinuity whose reflection exceeds the ARL and has a length which exceeds 1/4 inch will be identified as discrepant. Adjacent discontinuities whose reflections exceed the ARL, separated by less than 2L of sound metal (L = length of longest discontinuity) will be considered as a single discontinuity.

b. Any discontinuity whose reflection is less than the DRL will be acceptable. For class 2, the DRL will be increased to 40 percent of full screen height.

c. Discontinuities whose reflections are equal to or greater than the DRL, up to and including the ARL, will be evaluated as follows:

(1) If the discontinuity length exceeds the thickness of the thinner member it will be identified as discrepant. In no case will any single discontinuity length exceed 2 inches.

(2) Adjacent discontinuities separated by less than 2 L of sound metal (L - length of longest discontinuity) will be considered as a single discontinuity. The maximum distance between the outer extremities of any two such adjacent discontinuities or the sum of their lengths, whichever is greater, will not exceed the length specified in (1) above.

(3) If the total accumulative length of discontinuities in any 12 inches of weld length exceeds twice the thickness of the thinner member, that weld length will be identified as discrepant.

8.7.3.2 Full Penetration Tee Joints for Incomplete Root Penetration -- The provisions of paragraph 8.7.2.2 above will be applicable.

8.7.3.3 Partial and Full Penetration Tee Joints for Weld Depth -- The acceptance criteria of paragraph 8.7.2.3 above will apply.

8.7.3.4 Tee Joint Weld Discontinuities into the Through Member -- The standard for tee joint weld discontinuities into the through member will be as defined above in paragraph 8.7.2.4.

8.7.4 CLASS 3 ULTRASONIC ACCEPTANCE STANDARDS

8.7.4.1 Full Penetration Butt Welds and Corner Welds, Class 3 --

a. Any discontinuity whose reflection exceeds the ARL and has a length which exceeds 1/2 inch will be identified as discrepant. Adjacent discontinuities whose reflections exceed the ARL, separated by less than 2L of sound metal (L = length of longest discontinuity), will be considered as a single discontinuity.

b. Any discontinuity whose reflection is less than the DRL will be acceptable. For class 3 the DRL will be increased to 40 percent of full screen height.

c. Discontinuities whose reflections are equal to or greater than the DRL, up to and including the ARL, will be considered discrepant if the discontinuity length exceeds 1 inch or the thickness of the thinner member, whichever is greater.

d. Adjacent discontinuities separated by less than 2L of sound metal (L - length of longest discontinuity), will be considered as a single discontinuity. The maximum distance between the outer extremities of any two such adjacent discontinuities or the sum of their lengths, whichever is greater, will not exceed the length specified in "a" above for discontinuities having reflections above the ARL, or in "c" above for discontinuities having reflections equal to the DRL, up to and including the ARL. (See Figure 8-11.)

e. If the total accumulative length of discontinuities in any 12 inches of weld length exceeds twice the thickness of the thinner member, that weld length will be identified as discrepant.

8.7.4.2 Full Penetration Tee Joints for Incomplete Root Penetration -- The provisions of paragraph 8.7.2.2 above will be applicable.

8.7.4.3 Partial and Full Penetration Tee Joints for Weld Depth -- The acceptance criteria of paragraph 8.7.2.3 above will apply.

8.7.4.4 Tee Joint Weld Discontinuities into the Through Member -- The standard for tee joint weld discontinuities into the through member will be as defined above in paragraph 8.7.2.4.

9 / FORMING OF MATERIALS

9.1 SCOPE

This section covers the requirements for hot and cold forming of aluminum alloy materials used in the hull structure.

9.2 GENERAL

Materials will be formed as specified in this section. For materials not listed, hot or cold forming will be as recommended by the manufacturer.

9.3 COLD FORMING

9.3.1 GENERAL REQUIREMENTS -- Cold forming temperatures for 5083, 5454, or 5456 aluminum will not exceed 150°F. The radii of forming dies will be smooth and the area to be bent will be free of center punch marks, scratches, and heavy oxide scale. Minimum allowable bend radii for flat stock are shown in Table 9-1. These radii are applicable when the surface is free of heavy oxides, i.e. oxides which can not be removed with a rubber eraser.

Table 9-1. Cold Forming Minimum Bend Radii for Aluminum Alloys.

Alloy & Temper	Material Thickness, T (inches)				
	1/8	3/16	1/4	3/8	1/2 & Above
5454-0	1T	1T	1½ T	1½ T	2T
5454-H32	1½ to 2T	1½ to 2T	2 to 3T	2 to 4T	2½ to 5T
5454-H112	· NA*	NA*	2 to 3T	3 to 4T	3 to 5T
5456-0	1T	1 to 2T	1½ to 2T	2T to 3T	2T to 3T
5456-H116	2 to 3T	2 to 3T	2 to 3T	3 to 4T	3 to 4T

Note: Where a range of radii is shown, the smaller radius is applicable to bending perpendicular to the direction of rolling.

*Not applicable.

9.3.2 LUBRICANTS -- The use of lubricants which introduce staining or corrosion will be prohibited.

9.3.3 REPAIRS -- Required repairs to cold formed material surfaces will be made after forming.

9.4 CLEANING

Prior to and during forming operations, the material surfaces and forming dies will be clean, except for permissible lubricants, and free of all grit and contaminants.

9.5 HOT FORMING

Hot forming may be performed only when the reduction in physical properties can be tolerated and at time/temperature regimes that will not reduce the intergranular or exfoliation corrosion resistance of the material. When hot forming must be accomplished, it will be done using a procedure or process specification approved by NAVSEA.

10 / MATERIALS

10.1 SCOPE

This section contains requirements for procurement, receiving inspection, and storage of aluminum materials for the 3KSES hull structure. The requirements of this section are limited to those associated with wrought aluminum products, welding electrodes, and inert gases used in fabrication of the hull structure; requirements for other materials are contained in the applicable drawings and/or specifications.

10.2 PROCUREMENT DATA

10.2.1 STRUCTURAL MATERIALS

10.2.1.1 Identification -- Engineering drawings and/or bills of material will provide material identification including alloy type and temper, size, and procurement specification. Table 10-1 lists the primary aluminum materials for the 3KSES hull structure.

10.2.1.2 Ordering Data -- Material ordering documents will include the following data and requirements:

a. Number and date of the applicable specification.

b. Alloy, temper and form.

c. Dimensions required, e.g. thickness, size, shape, etc.

Table 10-1. 3KSES Aluminum Hull Structure Materials (Unwelded).

Alloy and Temper	Thickness	Description	Federal Specification	Minimum Strength Tensile	Minimum Strength Yield[2]	Elongation in. 2 in.
	(inches)			(ksi)	(ksi)	(percent)
5083-H111	up thru 5.000[1]	Extrusion	QQ-A-200/4[5]	40	24	12
5454-H32	0.050-0.249	Sheet	QQ-A-250/10	36	26	8
5454-H112	0.250-0.499	Plate	QQ-A-250/10	32	18	8
5454-H112	0.500-2.000	Plate	QQ-A-250/10	31	12	11
5454-H111	up to 5.000[1]	Extrusions	QQ-A-200/6[5]	33	19[3]	12
5456-H323	up to .188	Sheet	QQ-A-250/20	48	36	8
5456-H116	.160 to .250	Sheet	QQ-A-250/20	46	33	10
5456-H116	.250-1.250	Plate	QQ-A-250/20	46	33	12
5456-H116	1.251-1.500	Plate	QQ-A-250/20	44	31	12
5456-H116	1.501-3.000	Plate	QQ-A-250/20	41	29	12
5456-H111	up thru 5.000[1]	Extrusion	QQ-A-200/7[5]	42	26[4]	12

Notes:

(1) Properties valid for extrusion cross-section area up to 32 square inches.

(2) Yield strength at 0.2 percent offset in 2 inch gage length unless otherwise indicated.

(3) Yield strength at .0038 inches per inch extension under load.

(4) Yield strength at .0045 inches per inch extension under load.

(5) Mechanical properties for sizes not covered shall be as specified in the purchase order.

d. Level of preservation, packaging, and packing if other than Level C MIL-STD 649.

e. Inspection for internal defects shall be made by the supplier in accordance with MIL-I-8950. Acceptance Standards will be Class AA.

f. Identification marking will be in accordance with Federal Standard No. 184.

g. Marking for shipment will be in accordance with Federal Standard No. 123.

h. Mechanical properties for plate thicknesses or extrusion sizes that are not covered in the applicable specification.

i. Special mill order thickness tolerances on plates, when required, of either 2/3, 1/2, or less than 1/2 of the standard thickness tolerances shown in Table 10-2. (Availability and price of plates with special mill order tolerances are subject to negotiation with the mill.)

j. Dimensional tolerances for aluminum alloy wrought products that are not covered in Federal Standard No. 245. Standard dimensional tolerances for 5454 and 5456 plates and sheets are in Table 10-2.

k. Certification by Vendor -- Material certifications will be mandatory for all orders of hull structure material.

10.2.2 WELD FILLER MATERIAL

10.2.2.1 Identification -- Type 5556 filler material conforming to MIL-E-16053 will be the only filler material used to produce joints in or between Type 5083, 5454, and 5456 aluminum alloys.

Table 10-2. Standard Dimensional Tolerances for Type 5454 and 5456 Aluminum Alloy Sheet and Plate. (Ref. Fed. Std. No. 245 and ANSI H35.2-1975).

(a) Thickness Tolerances

SPECIFIED THICKNESS in.	SPECIFIED WIDTH—in.														
	Up thru 18	Over 18 thru 36	Over 36 thru 48	Over 48 thru 54	Over 54 thru 60	Over 60 thru 66	Over 66 thru 72	Over 72 thru 78	Over 78 thru 84	Over 84 thru 90	Over 90 thru 96	Over 96 thru 132	Over 132 thru 144	Over 144 thru 156	Over 156 thru 168
	TOLERANCE—in. plus and minus														
0.046-0.068	.0025	.003	.004	.005	.006	.006	.006	.007	.007	.008	.012	.013	...	...	...
0.069-0.076	.003	.003	.004	.005	.006	.006	.006	.007	.007	.012	.012	.016	...	...	...
0.077-0.096	.0035	.0035	.004	.005	.006	.006	.006	.007	.007	.012	.012	.016	...	...	...
0.097-0.108	.004	.004	.005	.005	.007	.007	.007	.008	.008	.016	.018	.020	...	...	...
0.109-0.125	.0045	.0045	.005	.005	.007	.007	.007	.008	.008	.016	.018	.020	...	...	...
0.126-0.140	.0045	.0045	.005	.005	.007	.010	.012	.013	.014	.016	.018	.020	...	...	...
0.141-0.172	.006	.006	.008	.008	.009	.012	.014	.015	.016	.017	.019	.023	...	...	...
0.173-0.203	.007	.007	.010	.010	.011	.014	.016	.017	.017	.017	.022	.026	...	...	...
0.204-0.249	.009	.009	.011	.011	.013	.016	.018	.018	.018	.018	.024	.028	...	...	...
0.250-0.320	.013	.013	.013	.013	.015	.018	.020	.020	.020	.020	.025	.030	.035	.042	.053
0.321-0.438	.019	.019	.019	.019	.020	.020	.023	.023	.025	.025	.026	.033	.038	.045	.057
0.439-0.625	.025	.025	.025	.025	.025	.025	.025	.030	.030	.030	.035	.035	.043	.049	.067
0.626-0.875	.030	.030	.030	.030	.030	.030	.030	.037	.037	.037	.045	.045	.054	.059	.077
0.876-1.125	.035	.035	.035	.035	.035	.035	.035	.045	.045	.045	.055	.055	.065	.070	.088
1.126-1.375	.040	.040	.040	.040	.040	.040	.040	.052	.052	.052	.065	.065	.075	.080	.098
1.376-1.625	.045	.045	.045	.045	.045	.045	.045	.060	.060	.060	.075	.075	.085	.090	.108
1.626-1.875	.052	.052	.052	.052	.052	.052	.052	.070	.070	.070	.088	.088	...	...	...
1.876-2.250	.060	.060	.060	.060	.060	.060	.060	.080	.080	.080	.100	.100	...	...	...
2.251-2.750	.075	.075	.075	.075	.075	.075	.075	.100	.100	.100	.125	.125	...	...	...
2.751-3.000	.090	.090	.090	.090	.090	.090	.090	.120	.120	.120	.150	.150	...	...	...
3.001-4.000	.110	.110	.110	.110	.110	.110	.110	.140	.140	.140	.160	.160	...	...	...
4.001-5.000	.125	.125	.125	.125	.125	.125	.125	.150	.150	.150	.160	...	...	...	...
5.001-6.000	.135	.135	.135	.135	.135	.135	.135	.160	.160	.160	.170	...	...	...	...

(b) Width Tolerances (Sheared flat sheet and plate)

SPECIFIED THICKNESS in.	SPECIFIED WIDTH—in.					
	Up thru 6	Over 6 thru 24	Over 24 thru 60	Over 60 thru 96	Over 96 thru 132	Over 132 thru 168
	TOLERANCE③—in.					
0.006-0.124	±1/16	±3/32	±1/8	±1/8	±5/32	—
0.125-0.249	±3/32	±3/32	±1/8	±5/32	±3/16	—
0.250-0.499	+1/4	+5/16	+3/8	+3/8	+7/16	+1/2

(c) Length Tolerances (Sheared flat sheet and plate)

SPECIFIED THICKNESS in.	SPECIFIED LENGTH—in.							
	Up thru 30	Over 30 thru 60	Over 60 thru 120	Over 120 thru 240	Over 240 thru 360	Over 360 thru 480	Over 480 thru 600	Over 600 thru 720
	TOLERANCES①—in.							
0.006-0.124	±1/16	±3/32	±1/8	±5/32	±3/16	±7/32	±9/32	—
0.125-0.249	±3/32	±3/32	±1/8	±5/32	±7/32	±1/4	±5/16	—
0.250-0.499	+1/4	+3/8	+7/16	+1/2	+9/16	+5/8	+11/16	+3/4

10.2.2.2 Ordering Data -- Filler material ordering documents will contain the following data and requirements.

a. Number (MIL-E-16053) and date of specification.

b. Filler material type, size (diameter), and spool size.

c. The supplier's quality assurance requirements - specifically, an inspection system in accordance with MIL-I-45208.

d. Packaging will conform to Level A of MIL-W-10430.

e. Packing will conform to Level A or B of MIL-W-10430.

f. Certification by Vendor -- Material certifications for each lot will be mandatory for all orders of filler material.

g. Chemical Composition -- Certified test results for each lot with exact chemical composition (not range) will be required for all orders of filler material where quantities are ordered direct from the mill or foundry.

h. Mechanical Properties -- Certified test results for each lot giving actual tensile values will be required where quantities are ordered direct from mill or foundary.

i. Sources -- Filler material may be ordered only from sources shown (mill or distributor) on Qualified Products List (QPL) 16053-84. For small lots available only from a jobber, a certificate that the filler metal shipped is qualified will be provided.

j. Special Condition -- All filler material will be ordered in the "shaved" condition to avoid the presence of surface oxides.

10.2.3 INERTING GASES

10.2.3.1 Identification -- Procurement specifications for inerting gases will be as follows:

Gas Type	Specification
Argon, Technical	MIL-A-18455
Helium, Technical	BB-H-1168

10.2.3.2 Ordering Data -- Ordering data for inerting gases will be as specified in Section 6 of the applicable specification. Grade B will be specified for helium.

10.3 MATERIAL RECEIVING AND INSPECTION

10.3.1 GENERAL -- Each lot of material received will be initially verified for identification,quantity and damage free condition. Inspection for conformance to quality requirements specified in the procurement document will then be performed before the material is released for storage or use in production. The method and extent of inspection or tests will be in accordance with the 3KSES Quality Program Plan TQPP001 (CDRL E012).

10.3.2 NON-CONFORMING MATERIAL -- Material received which is found to be non-conforming to the requirements of the procurement document will be conspicuously identified and retained, pending appropriate disposition, in an area or manner which will prevent inadvertent release for production use.

10.4 MATERIAL STORAGE AND HANDLING

10.4.1 STORAGE AND ISSUE -- Material will be stored in accordance with the supplier's or manufacturer's recommendation, unless superceding storage requirements are imposed with engineering approval. Material will be stored in designated controlled areas with adequate facilities to prevent damage and excessive deterioration. To minimize deterioration and expiration of shelf life (where applicable), materials will be issued for production on a first in-first out basis.

10.4.2 MATERIAL HANDLING --Handling equipment and facilities for movement of materials to and from storage will have adequate capability for the material being moved and will be operated in a manner to prevent damage during all handling operations .

10.4.3 MATERIAL AUDIT --Material in storage and handling operations will be audited periodically by Quality Assurance to assure compliance with requirements of the 3KSES Quality Program Plan (TQPP001).

10.5 RECORDS

Receiving inspection records and associated material data will be maintained in accordance with the provisions of Section 5 of this document.

11 / WELDING DESIGN

11.1 SCOPE

This section contains approved joint designs and joint efficiency requirements for use in the design and fabrication of the 3KSES hull structure. Data for selecting or calculating weld sizes that will provide the required joint strength or efficiency are included.

11.2 GENERAL

Full penetration, partial penetration, fillet, or combination welds will be made in the aluminum hull structure materials with the filler material specified in Section 10. Weld joints will be in accordance with the requirements of this section.

11.3 JOINT EFFICIENCY

Joint efficiency will be based on the minimum as-welded tensile strength, as specified herein, of the weaker joined member where the weaker member is defined as that member which has the lower product of thickness and minimum ultimate tensile strength. The efficiency or strength of continuous double fillet welded tee or lap joints will be determined as specified in paragraph 11.6.1. Full penetration welds, where compatible weld metal is used with ultimate tensile strength equivalent to or greater than that of the annealed base metal, are considered to be 100 percent efficient subject to the limitations described in the sections which follow.

11.4 JOINT CLASSIFICATION

Welded joints described herein are standard. Welding symbols in accordance with ANSI/AWS A2.4-76 "Symbols for Welding and Nondestructive Testing" will be used on engineering drawings. A chart of these symbols is presented in Figure 11-2, and the use of selected symbols for various joint designs is illustrated on the figures in this section. Structural joints may also be designated on engineering drawings using the joint numbering system described in Figure 11-1.

11.4.1 BUTT JOINTS (B) -- Butt welded joints, when used, will be subject to the limitations specified in Figures 11-3 through 11-11 and the following:

a. Full penetration butt joints welded from both sides are considered to be 100 percent efficient.

b. When a backing strip is used in a butt joint and remains on the joint, the joint will be considered to have a maximum efficiency of 90 percent.

c. Butt-type joints welded against temporary backing or against backing which is removed, and on which the root is inspected and passes the required nondestructive tests, will be considered the equivalent of a full penetration joint welded from both sides with efficiency equal to 100 percent.

d. Butt-type joints welded from one side without backing will be avoided. Such joints will however, be acceptable provided that, when the root side is not accessible for inspection, the joint efficiency is limited to 80 percent and the joint is not subjected to root bending tension. If the root side of the joint is accessible and the root passes the required nondestructive tests, the joint will be considered the equivalent of a full penetration joint welded from both sides.

The structural joint numbering system is composed of four character groups. By means of the four groups, a unique identification is assigned to each joint design. As an example:

B 2 V . 1

First character(s) (letter(s)) designates type of joint:

- B - Butt joint
- C - Corner joint
- E - Edge joint
- L - Lap joint
- T - Tee joint
- PT - Partial penetration tee joint
- FT - Double-fillet tee joint

Second character (number) designates number of sides welded:

- 1 - Welded from one side
- 2 - Welded from both sides

Third character (letter) designates configuration of joint:

- S - Square groove
- V - Bevel or V groove
- U - U groove
- J - J groove

Period used for separation

Fourth character (number) is assigned in sequence, 1, 2, 3, etc., to cover distinctive joint differences such as bevel angle, root opening, with backing, without backing, etc.

Figure 11-1. Structural Joint Numbering System.

AMERICAN WELDING SOCIETY

STANDARD WELDING SYMBOLS

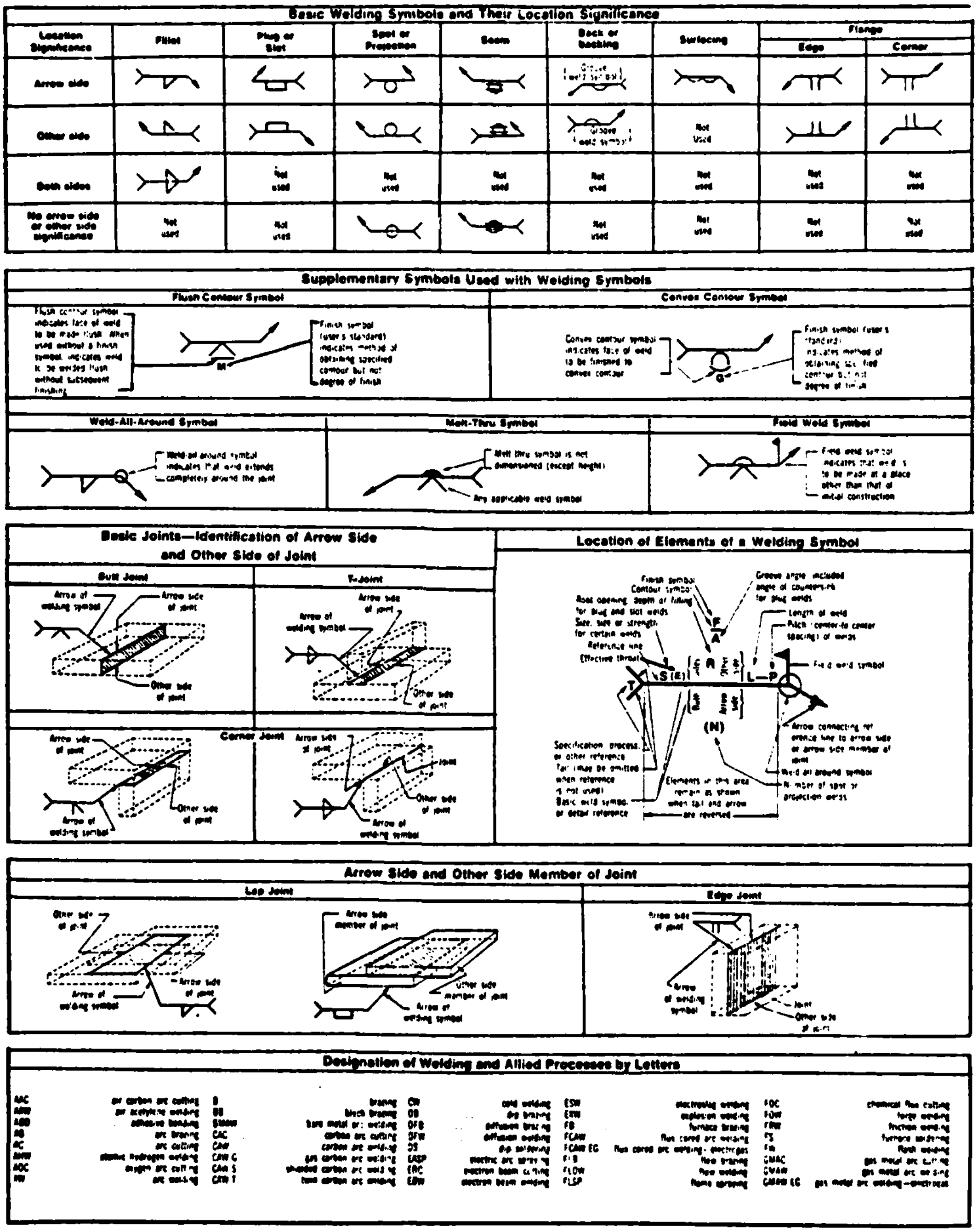


Figure 11-2. Welding Symbols Summary Chart (Sheet 1 of 2).

AMERICAN WELDING SOCIETY
STANDARD WELDING SYMBOLS

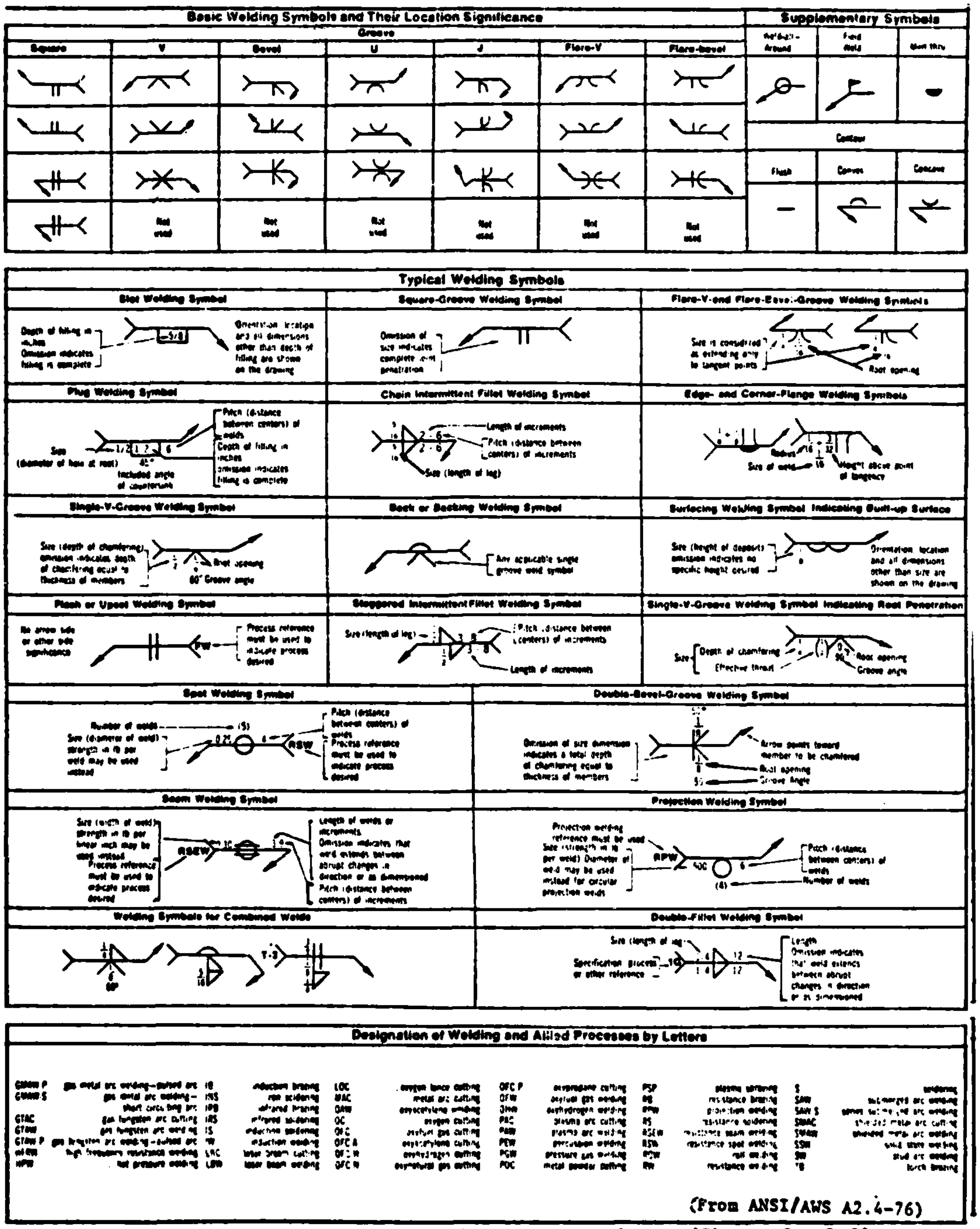


Figure 11-2. Welding Symbols Summary Chart (Sheet 2 of 2).

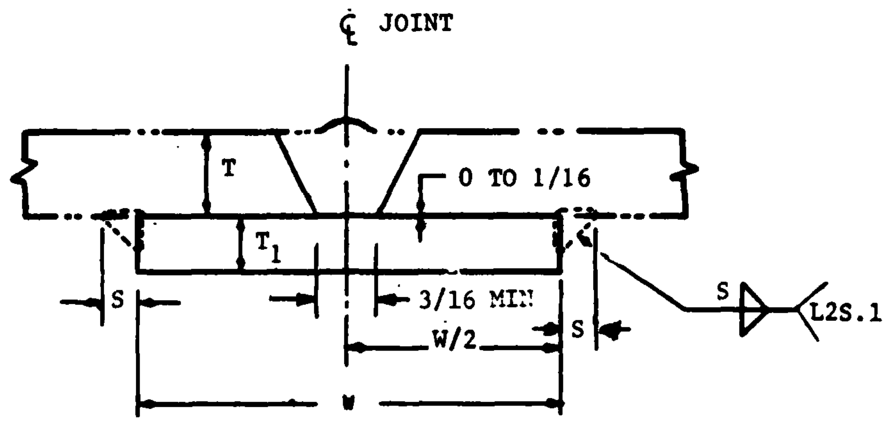
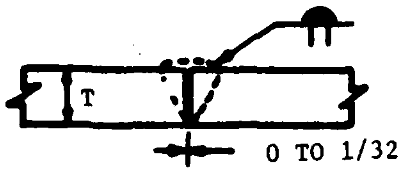


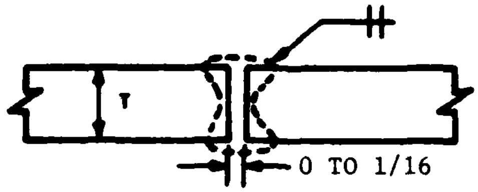
PLATE THICKNESS - (T) (inch)	T_1 MIN (inch)	W MIN (inch)
UP THRU 1/8	1/8	1
OVER 1/8 THRU 5/16	3/16	1-1/2
OVER 5/16	1/4	2

1. $S = (1/2)T_1$, but in no case less than 1/8 inch or greater than 1/4 inch.
2. When shapes are used in lieu of backing strap, all above dimensions and notes will apply.
3. Butt joints in permanent backing straps will be welded, but need not comply with the NDT requirements applicable to the welded joint itself except for fatigue sensitive joints.

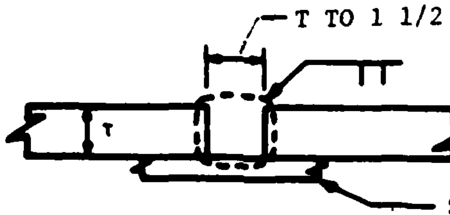
Figure 11-3. Permanent Backing Strap.



B1S.1 WELDED ONE SIDE



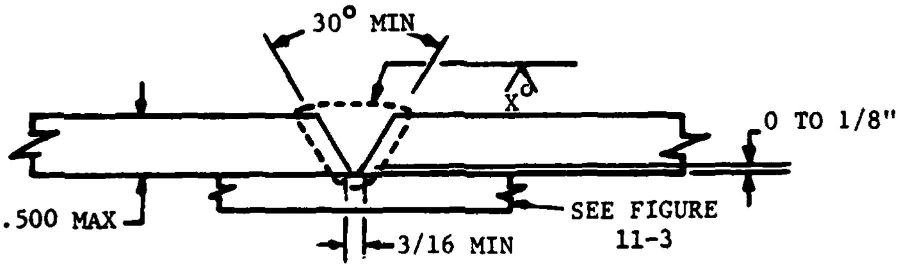
B2S.1 WELDED BOTH SIDES



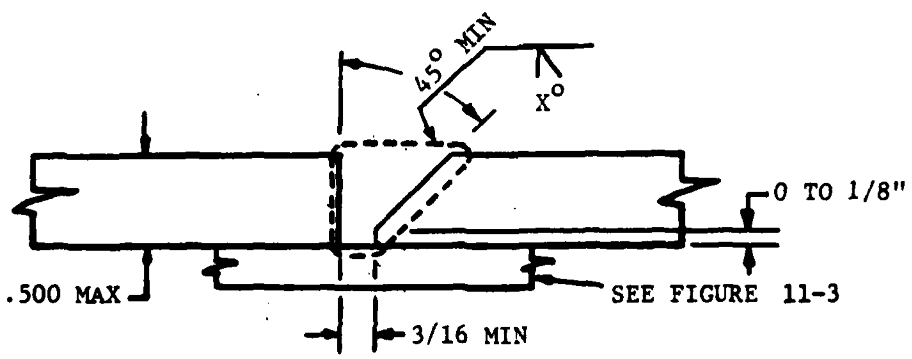
B1S.2 WELDED ON BACKING

JOINT	MAXIMUM THICKNESS "T" INCH		
	FLAT POSITION	OVERHEAD & VERT. POSITION	HORIZONTAL POSITION
B1S.1	1/4	1/4 Vert. Only	3/16
B2S.1	1/4	1/4	1/4
B1S.2	Unlimited	Unlimited	Unlimited

Figure 11-4. Butt Joints, Square

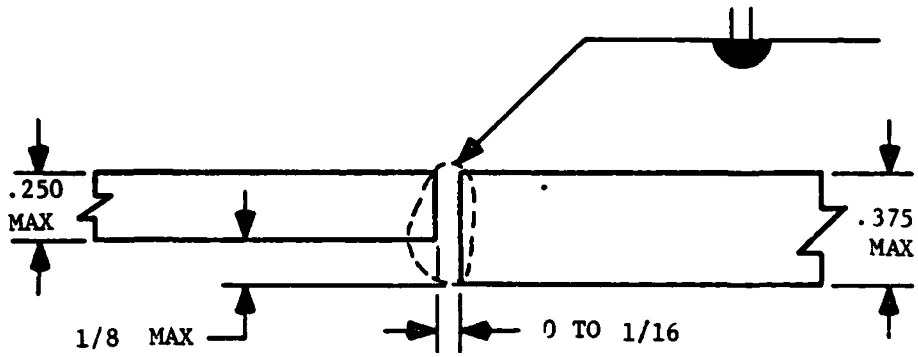


B1V.1 SINGLE-V

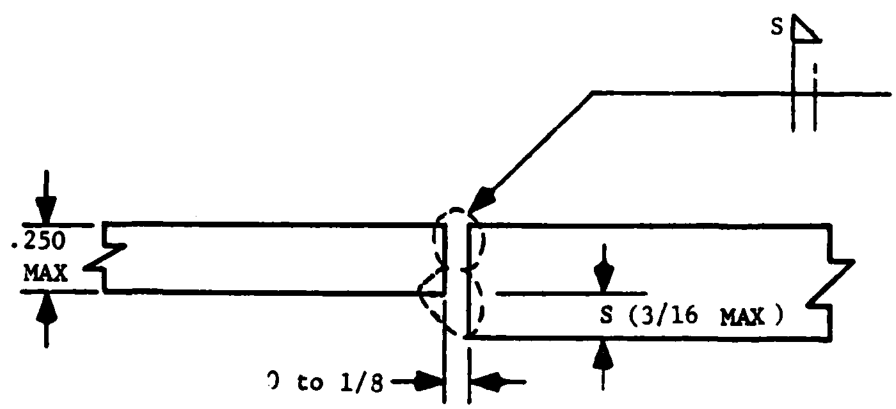


B1V.2 SINGLE BEVEL

Figure 11-5. Butt Joints, Welded on Backing

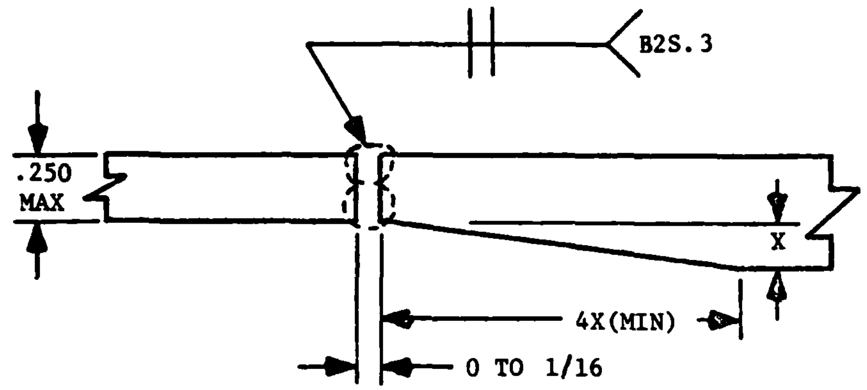


B1S.3 WELDED ONE SIDE

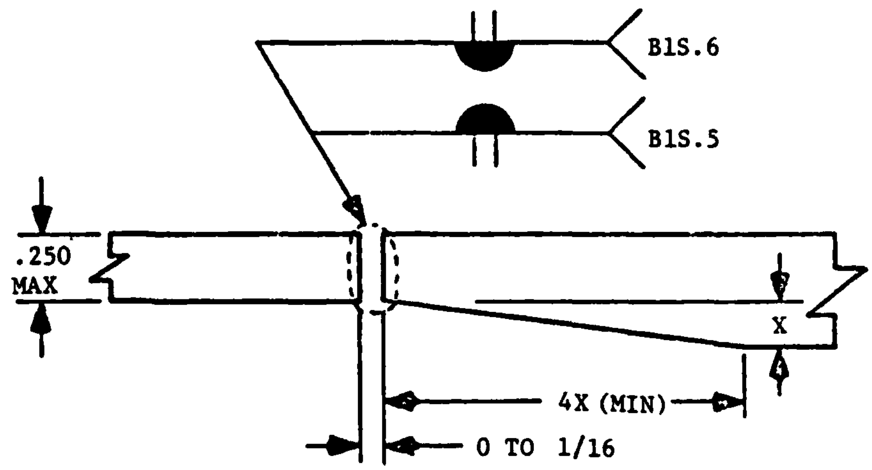


B2S.2 WELDED BOTH SIDES

Figure 11-6. Butt Joints, Dissimilar Thickness, Square

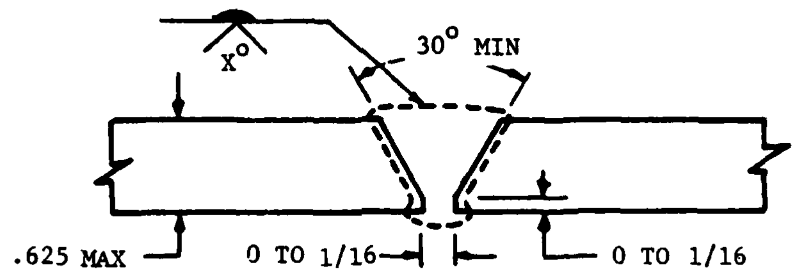


WELDED BOTH SIDES

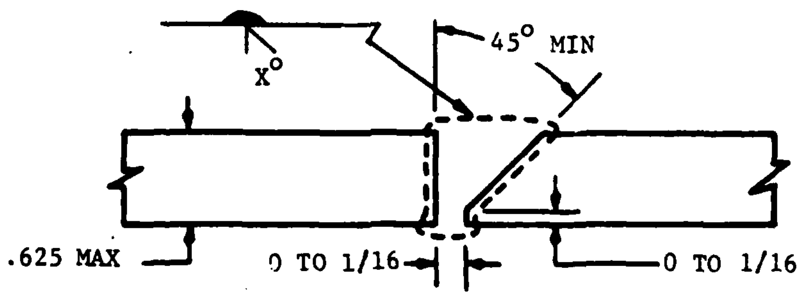


WELDED ONE SIDE

Figure 11-7. Butt Joint, Dissimilar Thickness Tapered, Square

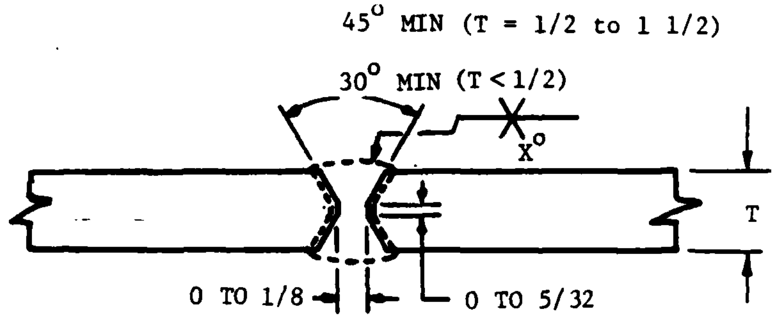


B1V.3 SINGLE-V

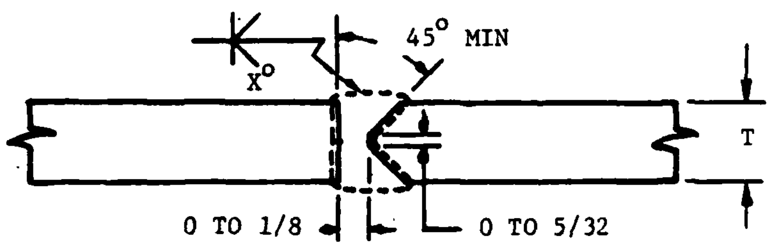


B1V.4 SINGLE-BEVEL

Figure 11-8. Butt Joints, Single-V and Single-Bevel, Welded From One Side With Temporary Backing



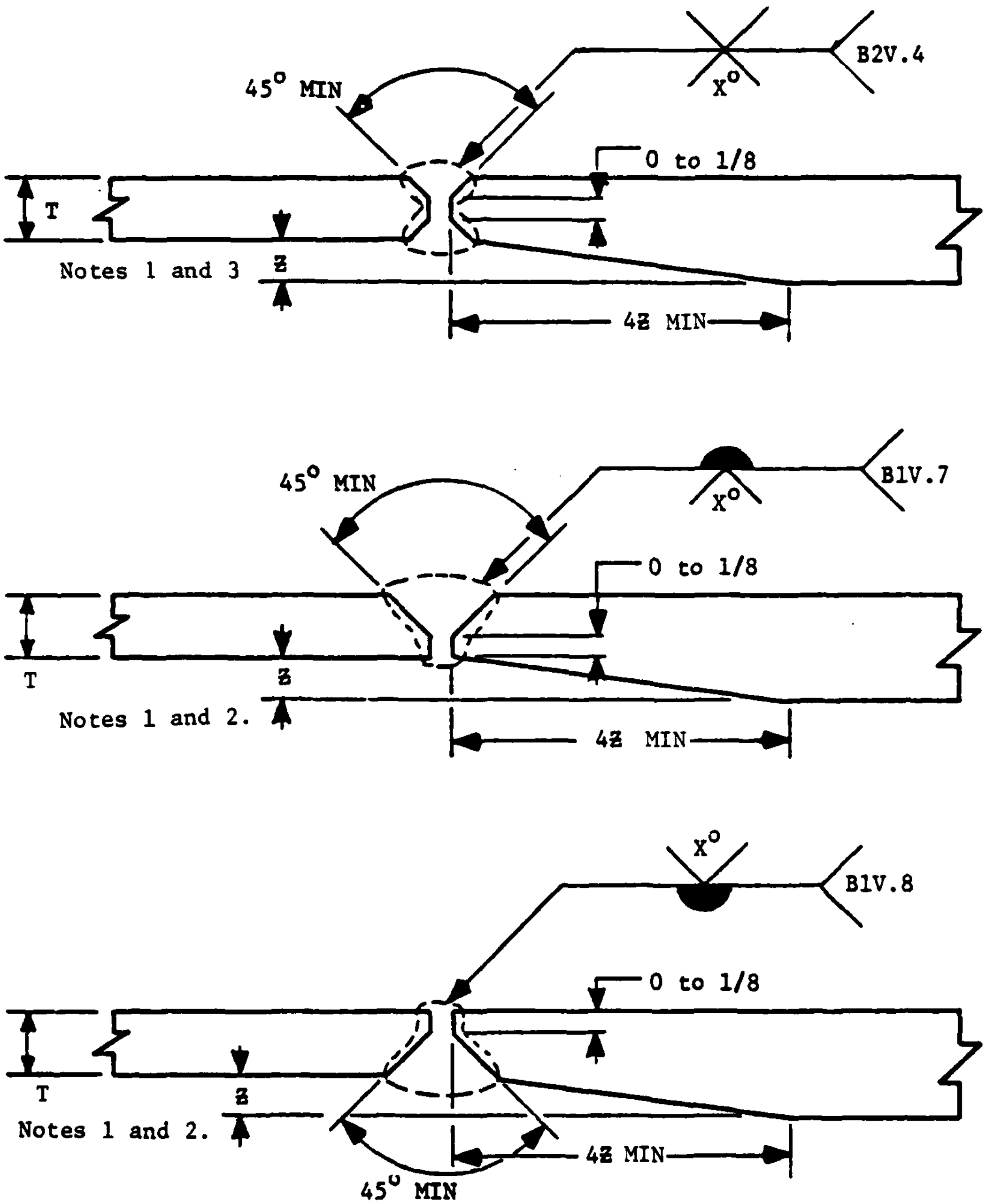
B2V.1 DOUBLE-V



B2V.2 DOUBLE-BEVEL

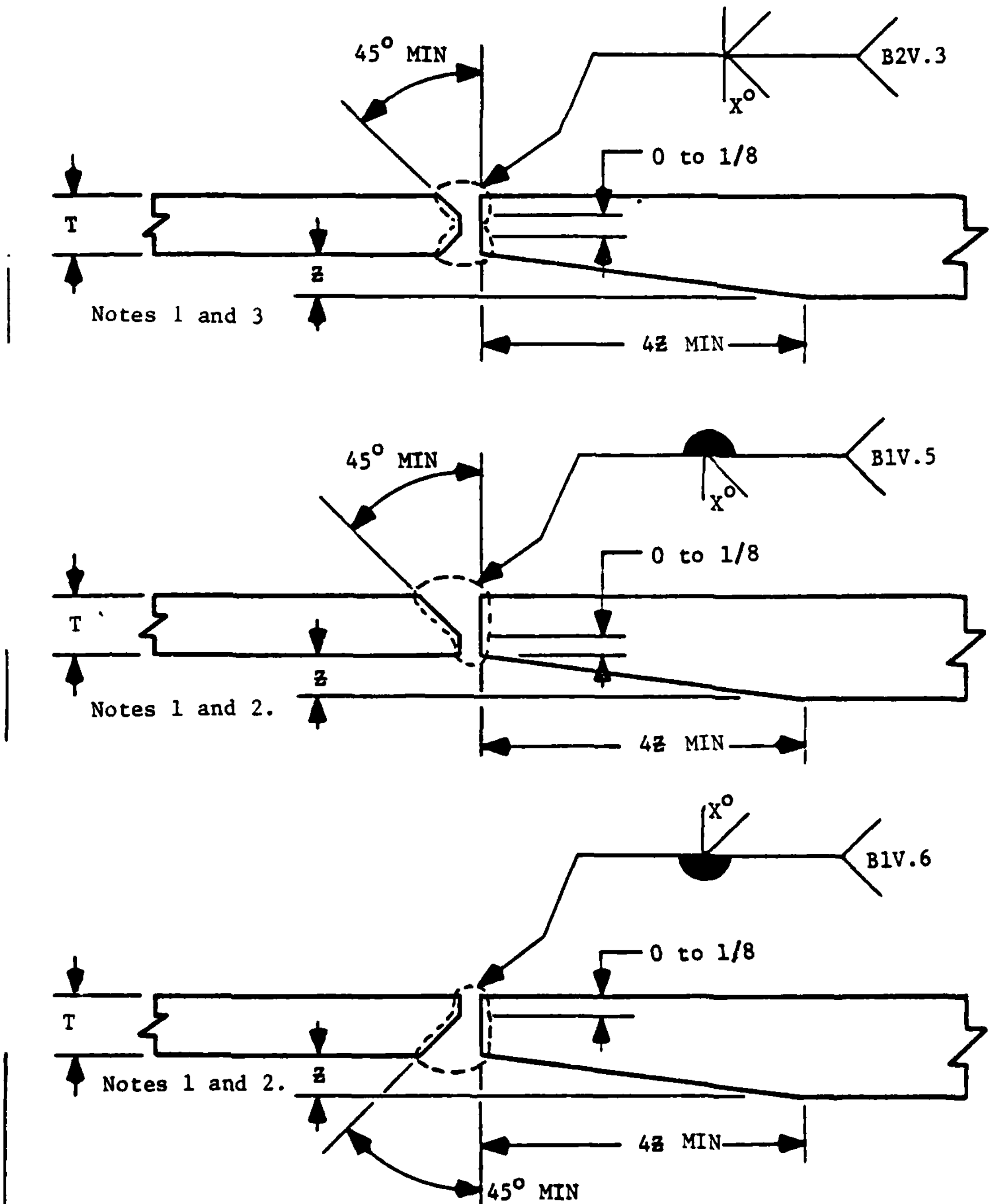
T = 1 1/2 MAX

Figure 11-9. Butt Joints, Double-V and Double-Bevel, Welded Both Sides



Notes:
1. Z Max. = .500
2. T Min. = .160; T Max.= .625
3. T Min. = .160; T Max.= 1.500

Figure 11-10. Butt Joint, Dissimilar Thickness Tapered, Bevel, Welded One Side or Both Sides.



Notes: 1. Z Max. = .500
2. T Min. = .160 ; T Max.= .625
3. T Min. = .160; T Max.= 1.500

Figure 11-11. Butt Joint, Dissimilar Thickness Tapered, V, Welded One Side or Both Sides.

11.4.2 TEE-JOINTS -- Tee Joints, when used, will be subject to the limitations specified in Figures 11-12 through 11-15 and the following:

11.4.2.1 Full Penetration Tee Joints (T) -- Full penetration tee joints, when used, will be made with bevel or J-groove welds with reinforcing fillets. Typical weld geometries for full penetration tee joints are illustrated in Figures 11-13 and 11-14.

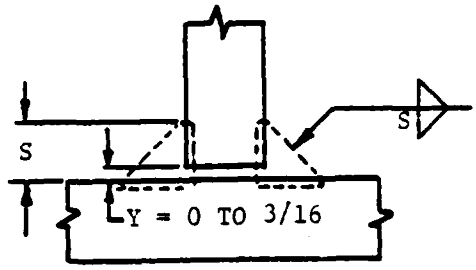
a. Full penetration tee joints welded from both sides are considered to be 100% efficient.

b. Full penetration tee joints welded from one side against permanent backing will be considered to have a maximum efficiency of 90 percent.

c. Full penetration tee joints welded against temporary or removable backing, and on which the root is inspected and passes the required nondestructive tests, will be considered to be 100% efficient.

d. Full penetration tee joints welded from one side without backing will be avoided; when such joints are unavoidable, the joint efficiency will be limited to 80%.

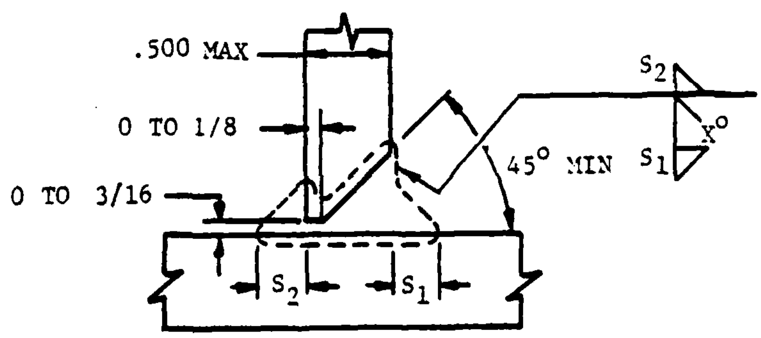
11.4.2.2 Partial Penetration Tee Joints (PT) -- A partial penetration tee joint, when used, will be made with a bevel or J-groove weld with a reinforcing fillet. Bevel or J-groove partial penetration tee joints will meet the design requirements of paragraph 11.6.2 . Typical weld geometry for partial penetration tee joints is illustrated in Figure 11-15.



FT2S.1 CONTINUOUS DOUBLE-FILLET-WELDED

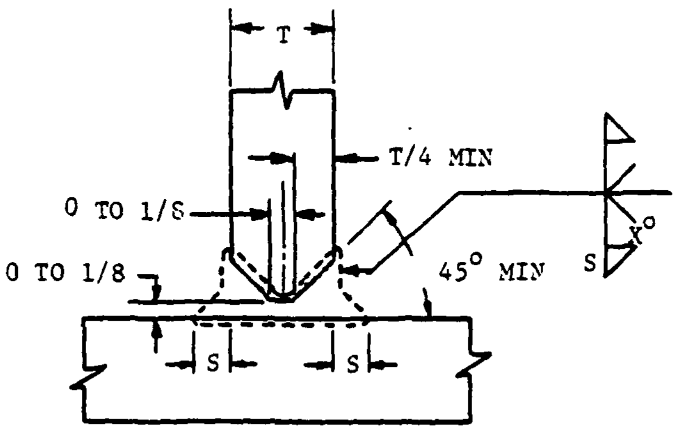
NOTE: Where Y is greater than 1/16 inch as a nominal condition, S will be increased by an amount equal to the opening above 1/16 inch.

Figure 11-12. Tee Joint, Fillet-Welded.



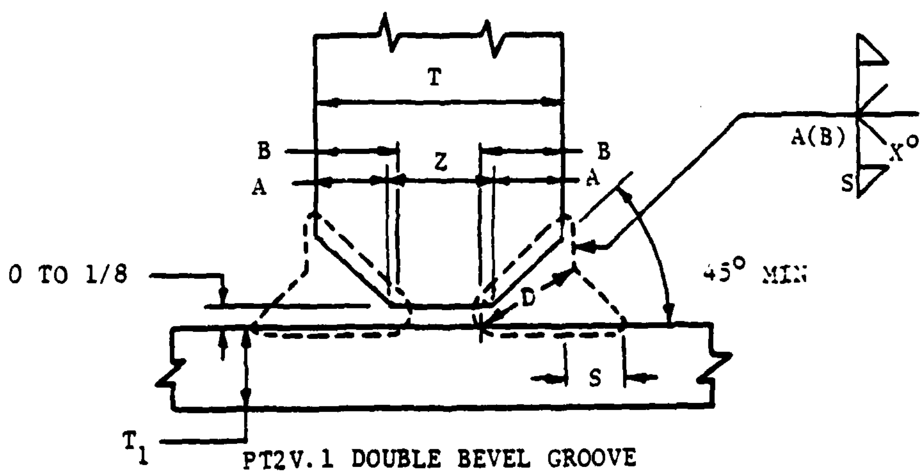
T2V.1 WELDED BOTH SIDES

Figure 11-13. Full Penetration Tee Joint, Single Bevel, Fillet Reinforced.



T2V.2 DOUBLE-BEVEL, WELDED BOTH SIDES

Figure 11-14. Full Penetration Tee Joint, Double Bevel, Fillet Reinforced.



PT2V.1 DOUBLE BEVEL GROOVE

Figure 11-15. Partial Penetration Tee Joint, Double Bevel, Fillet Reinforced.

11.4.2.3 Continuous Double-Fillet Welded Tee Joints (FT) -- Continuous double-fillet weld sizes and efficiencies will be computed in accordance with paragraph 11.6.1. Intermittent fillet welding will not be used.

11.4.2.4 Canted Tee Joints -- Where partial and full penetration tee welded elements are canted to form connections at an angle other than 90°, the following will apply:

a. The angle of the bevel on the closed side of bevel or J-groove joints should be corrected to provide the minimum included angle specified for each joint type.

b. When partial penetration joints are used for attachment of structural members to each other, and the angle formed between the tee member and the through plate is greater than 105° on the open or obtuse angle side of the joint, a bevel will be provided at this side of the joint sufficient to produce an included angle of 45° minimum.

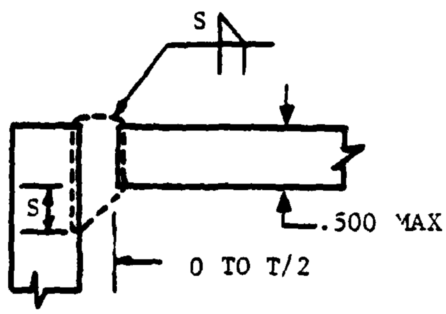
11.4.3 CORNER JOINTS (C) -- Corner joints, when used, will be subject to the limitations specified in Figures 11-16 through 11-19 and the following:

a. Full penetration corner joints welded from both sides are considered to be 100% efficient.

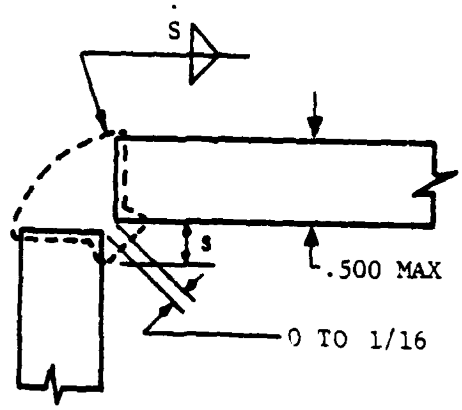
b. When a backing strap is used in a corner joint and remains on the joint, the joint will be considered to have a maximum efficiency of 90%. If the backing strap is removed and the root passes the required nondestructive tests, the joint will be considered the equivalent of a full penetration corner joint welded from both sides.

c. Corner joints welded from one side without backing will be avoided; when such joints are unavoidable, the joint efficiency will be limited to 80%.

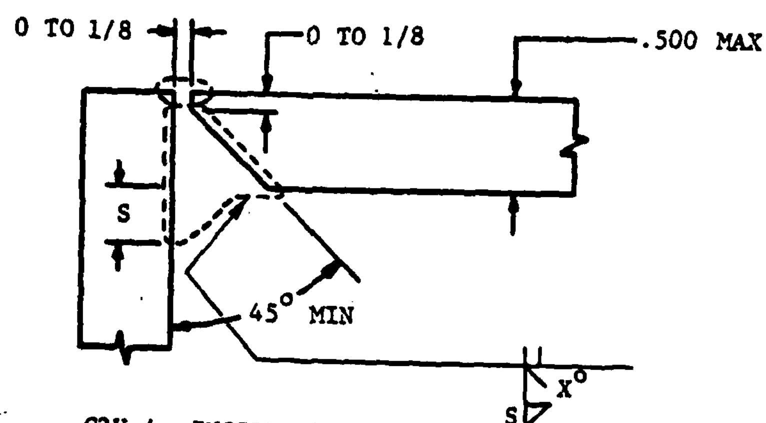
11.4.4 LAP JOINTS (L) -- Plug and slot weld joints, fillet-welded lap joints, and other similar fillet-welded joints not covered under Tee Joints in Paragraph 11.4.2 may be used subject to the limitations specified below.



C2S.1 OPEN SQUARE



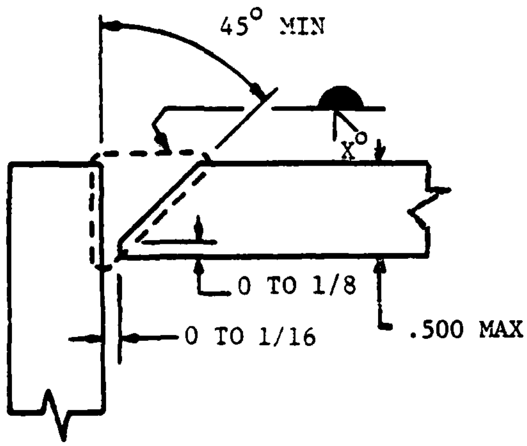
C2S.3 OUTSIDE SQUARE



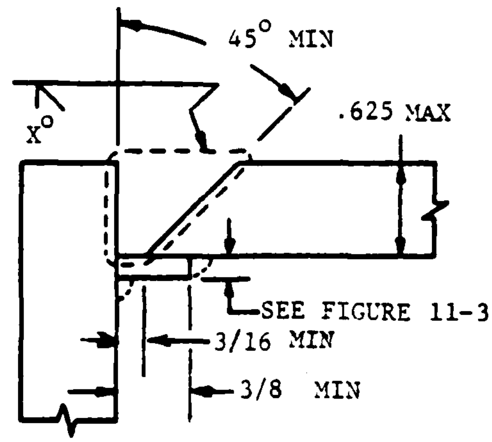
C2V.4 INSIDE SINGLE BEVEL

Figure 11-16. Corner Joints; Fillet Reinforced, Welded Both Sides.

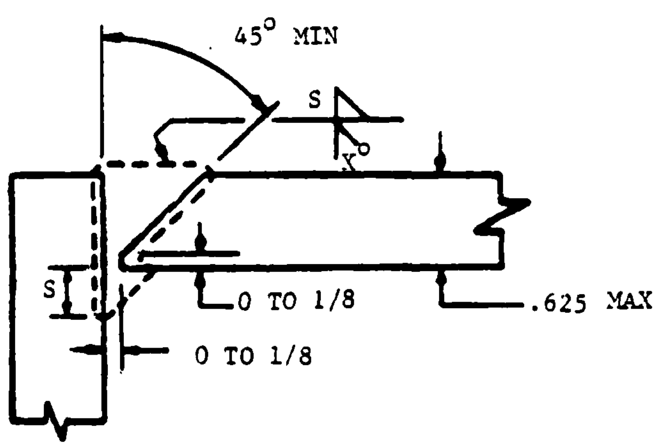
11-1



C1V.2 TEMPORARY BACKING
WELDED ONE SIDE

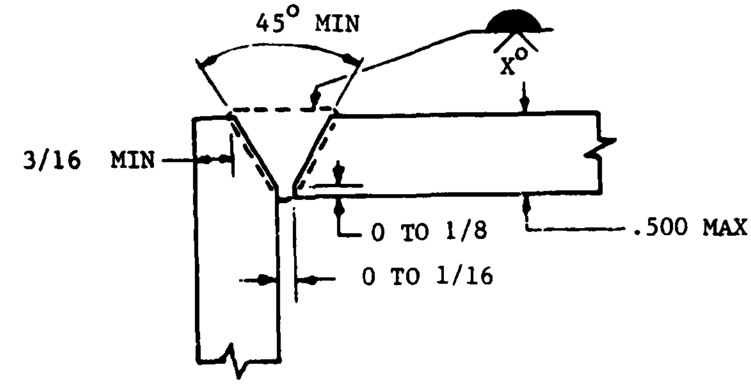


C1V.5 PERMANENT BACKING
WELDED ONE SIDE

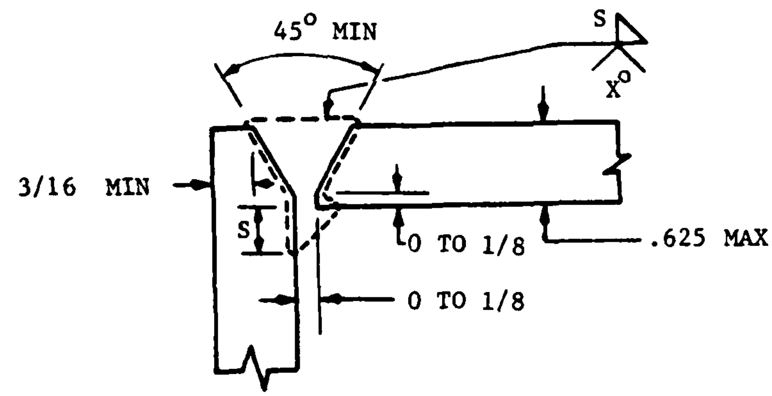


C2V.2 FILLET REINFORCED
WELDED BOTH SIDES

Figure 11-17. Corner Joints, Outside Single Bevel.

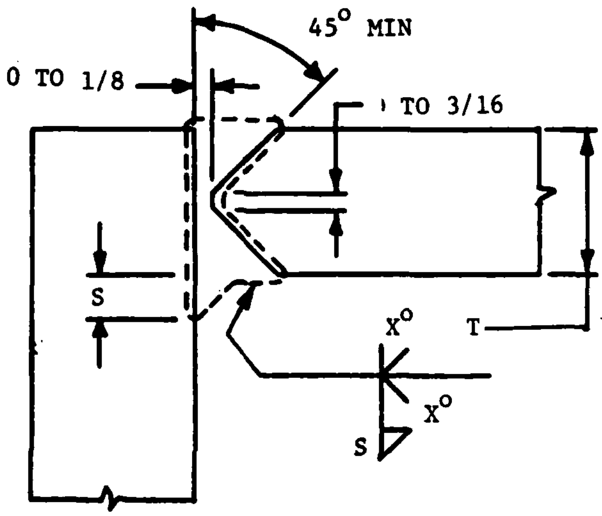


C1V.1 WELDED ONE SIDE (WITH BACKING)

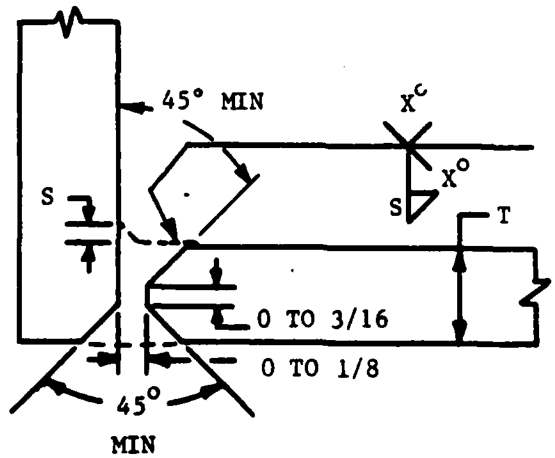


C2V.1 WELDED BOTH SIDES, FILLET REINFORCED

Figure 11-16. Corner Joints, Outside Single-V



C2V.4 WELDED BOTH SIDES



C2V.5 WELDED BOTH SIDES

Figure 11-19. Corner Joint, Double-Bevel, Fillet-Reinforced

11.4.4.1 Fillet-Welded Lap Joints -- Fillet welded lap joints, when used, will be subject to the limitations specified in Figure 11-24. Strengths of fillet-welded lap joints shall be determined in the same manner as for fillet-welded tee joints in accordance with paragraph 11.6.1. Where 100 percent efficiency is required, these joints will be restricted to plating less than 1/4 inch thick. Fillet welded lap joints will be used only in applications where faying surfaces are sealed.

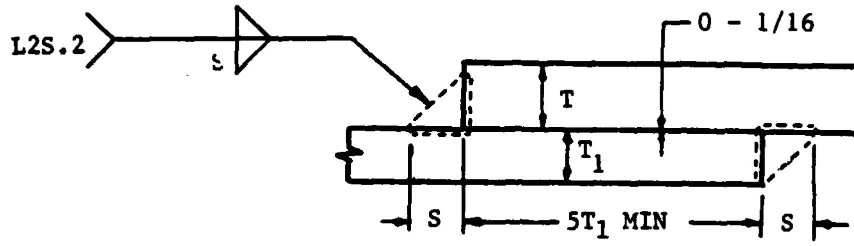
11.4.4.2 Plug and Slot Welds Joints -- These weld joints will be avoided whenever possible in primary hull structure.

11.4.5 STUD WELDS -- Studs may be welded to the face of flanges, to plating opposite the webs of shapes or flat bars, and as approved by Engineering. The stud diameter, or the thickness of rectangular studs, will not exceed twice the thickness of the material to which it is welded. The width of rectangular studs should not exceed 5 times the thickness.

11.4.6 OTHER JOINT DESIGNS -- When joint configurations other than those authorized by this section are employed, the joint design and inspection requirements will be detailed on the engineering drawing. A specific welding procedure will be developed and qualified for each such joint unless that joint is inspected and meets the specified inspection requirements.

11.5 DESIGN REQUIREMENTS

All butt joints will be full penetration 100 percent efficient joints except for joints made where the root is not inspected and in special cases substantiated by stress analysis. Butt joints with efficiencies less than 100% will be identified on detail drawings by noting the maximum allowable (or required) efficiency in the tail of the welding symbol. Tee-joints for structures on which stress analysis is performed will be sized for the maximum design loads and the applicable factors of safety. The size welds for structures that are not subjected to stress analysis will be based on the joint efficiencies specified in Table 11-1.



NOTE: Size of fillet shall be governed by design requirements.

Figure 11-20. Lap Joint, Double-Fillet-Welded

Table 11-1. Weld Joint Efficiency (Sheet 1 of 5).

B = Butt joint
T = Full penetration grooved tee joint
PT = Partial-penetration tee joint
FT = Double-fillet tee joint
C = Corner Joint
L = Lap joint

FOR USE IN LIEU OF STRESS ANALYSIS (SEE PARAGRAPH 11.5)

ITEM	CONNECTION	JOINT EFFICIENCY (PERCENT)	JOINT DESIGN CLASSIFICATION
APPENDAGES	FENCE		
	Butts and seams	100	B
	Connections to fence cap		
	Plating	90	B
	Formers	75	T, PT, FT
	Connections to hull	90	B, T
	Plating to frames, stiffeners and webs	75	T, PT, FT
	FIN		
	Butts and seams	90	B
	Plating to web and closure members	75	B, T, PT, FT, L
	SPRAY RAIL		
	Butts and seams	80	B, C
	Connections to hull	80	B, T
	Formers to plating	60	T, PT, FT
BRACKETS	OTHER THAN TRIPPING		
	Doors and openings; trunks and hatches	75	T, PT, FT, C, L
	Frames	75	T, PT, FT, L
	Lightened or truss floors and longitudinals	75	T, PT, FT, L
	Solid floors and unlightened longitudinals	100	T, PT, FT, L
	Shell plating	75	T, PT, FT, L
	Tangency or tilting brackets:		
	To webs and faceplates	50	T, PT, FT
	To bulkheads (based on bracket thickness)	75	T, PT, FT
	TRIPPING	60	T, PT, FT
BREASTHOOKS	Butts and seams	100	B
	Connections to shell	75	T, PT, FT, L
	Connections to decks, longitudinals, stiffeners and intersecting bulkheads when breasthook is a continuation of longitudinal structure.	100	B, T, PT, FT
	Elsewhere	75	T, PT, FT, L

Table 11-1. Weld Joint Efficiency (Sheet 2 of 5).

ITEM	CONNECTION	JOINT EFFICIENCY (PERCENT)	JOINT DESIGN CLASSIFICATION
BULKHEADS, LONGITUDINAL AND TRANSVERSE	Butts and seams	100	B
	Doors and openings		
	Coaming to plating:		
	Structural bulkheads	100	T, PT, FT
	Elsewhere	75	T, PT, FT
	Stiffener ends to coaming:	75	T, PT, FT
	Interface tee members		
	Where slotted in way of through members, connections to passing members and collar plates if used		
	Structural bulkheads	100	T, PT, FT, L
	Swash bulkheads	60	T, PT, FT, L
	Horizontal member webs to decks and webs to flanges if built-up:		
	Main subdivision bulkheads	100	T, PT, FT
	Other structural bulkheads		
	At ends for 1/8 length (but not less than 10 inches or more than one frame or stiffener space)	100	T, PT, FT
	Elsewhere	75	T, PT, FT
	Swash bulkheads		
	At ends for 1/8 length (but not less than 10 inches or more than one frame or stif-fener space)	75	T, PT, FT
	Elsewhere	50	T, PT, FT
	Horizontal member webs to webs		
	Structural bulkheads	100	T, PT, FT
	Swash bulkheads	75	T, PT, FT
	Horizontal member flanges to flanges	100	B
	Vertical member webs to bulkheads, webs to webs, webs to flanges if built up and flanges to flanges:		
	Structural bulkheads	100	T, PT, FT
	Swash bulkheads	75	T, PT, FT
	Joiner bulkhead peripheral attachment members to hull structure	50	T, PT, FT, L
	Plating periphery:		
	Main subdivision bulkheads	100	T, PT, FT
	Other structural bulkheads		
	At ends for 1/8 length (but less than 10 inches or more then one frame or stiffener space)	100	T, PT, FT, L
	Elsewhere	75	T, PT, FT, L
	Swash bulkheads		
	At ends for 1/8 length (but not less than 10 inches or more than one frame or stiffener space)	75	T, PT, FT, L
	Elsewhere	50	T, PT, FT, L
	Plating where slotted in way of through members:		
	Connections to passing members and collar plates:		
	Structural bulkheads	100	T, PT, FT, L
	Swash bulkheads	60	T, PT, FT, L
	Stiffeners		
	Webs to bulkheads and to flanges if built-up	60	T, PT, FT
	Webs and flanges to decks, platforms and interface tee flanges	100	T, PT, FT

Table 11-1. Weld Joint Efficiency (Sheet 3 of 5).

ITEM	CONNECTION	JOINT EFFICIENCY (PERCENT)	JOINT DESIGN CLASSIFICATION
CLOSURE PLATES	All joints	90	B
COMPENSATION FOR HOLES IN STRUCTURE	Shell plating, Main, 01 and Wet Decks and attached stiffeners and framing	100	T, PT, FT, C, L
	Bulkheads, 2nd and 3rd Decks, floors and attached stiffeners and framing		
	WT, OT, or continuous structure	75	T, PT, FT, C, L
	NT or intercostal structure	50	T, PT, FT, C, L
DECKS AND PLATFORMS	Butts and seams	100	B
	Stiffener webs to plating and to flanges if built-up		
	Wet Deck	75	T, FT, PT
	Elsewhere	60	T, FT, Pt
	Plating periphery (except superstructure)		
	To bulkheads	(see BULKHEADS)	
	To shell and transom	75	B, T, PT, FT, L
	Trunks and hatches		
	Coaming to plating		
	01, Main and Wet Decks	100	T, PT, FT, C, L
	Elsewhere	75	T, PT, FT, C, L
	Stiffener ends to coaming		
	01, Main and Wet Decks	100	T, PT, FT
	Elsewhere	75	T, PT, FT
FOUNDATIONS (including framing used as foundations)	Machinery foundations and sub-bases		
	Main connections	100	B, T, PT, FT, C, L
	Brackets	60	T, FT, C, L
	Mooring equipment foundations		
	Main connections	100	B, T, PT, FT, C, L
	Brackets	75	T, PT, FT, C, L
	Weapon and antenna foundations		
	Main connections	100	B, T, PT, FT, C, L
	Brackets	75	T, PT, FT, C, L
	Other foundations		
	Main connections	100	B, T, PT, FT, C, L
	Brackets	50	T, PT, FT, C, L
FRAMING, LONGITUDINAL AND TRANSVERSE	Butts and seams of plating	100	B
	Butts of shapes	100	B
	Connections where slotted in way of through members:		
	To passing members and collar plates, if used:		
	Continuous framing	100	T, PT, FT, L
	Intercostal framing	75	T, PT, FT, L
	Intercostal framing, but part of continuous structure	100	T, PT, FT, L
	End connections to intersecting members		
	Deep web members (24 inches or more in depth) including floors:		
	At flanges and adjacent 25 percent of web	100	B, T, PT, FT, L
	Elsewhere	75	B, T, PT, FT, L
	Ordinary web frames (less than 24 inches in depth)	100	B, T, PT, FT, L

Table 11-1. Weld Joint Efficiency (Sheet 4 of 5).

ITEM	CONNECTION	JOINT EFFICIENCY (PERCENT)	JOINT DESIGN CLASSIFICATION
FRAMING, LONGITUDINAL AND TRANSVERSE (Continued)	Openings in webs		
	Coamings to plating	75	T, PT, FT, C, L
	Stiffeners or chocks to coaming	75	T, PT, FT, C, L
	Truss framing		
	Brackets	60	T, PT, FT
	Gussets and chocks	(See BRACKETS)	
	Vertical and diagonal member end connections	100	B, T, PT, FT
	Web connections to structure supported and to flanges, if built-up		
	Shell and transom	75	T, PT, FT
	01, Main and Wet Decks	75	T, PT, FT
	Elsewhere	60	T, PT, FT
MAST	Butts and seams	90	B, C
	Connections to hull and superstructure	75	B, T, PT, FT
	Framing including struts		
	Flange end connections	100	B, T, FT
	Gussets		
	When used as end connections	100	B, T, FT
	Elsewhere	75	B, T, PT, FT, C, L
	Webs to plating and to flanges if built-up	75	T, PT, FT
	Foundations		
	Gussets and chocks	75	B, T, PT, FT, C, L
	Main connections	100	B, T, FT
	Openings in webs		
	Coaming to plating	75	B, T, PT, FT, C, L
	Stiffeners to coaming	75	T, PT, FT, C
	Platforms		
	Periphery to plating	75	T, PT, FT
	Where slotted in way of through members:		
	To passing member and collar plates if used	60	T, PT, FT, L
	Stiffeners		
	Flange end connections	75	B, T, PT, FT
	Webs to plating and to flanges if built-up	60	T, PT, FT
SHELL PLATING, INCLUDING TRANSOM	Butts and seams	100	B, C
	Stiffener webs to plating and to flanges, if built-up	75	T, PT, FT
STANCHIONS	Butts and seams of welded stanchions	80	B
	Gussets	75	T, PT, FT
	Head and heel connections	90	T, PT, FT
SUPERSTRUCTURE	Butts and seams	100	B, C
	Connections to hull proper (01 Level)		
	Superstructure bulkheads		
	Plating	60	T, PT, FT
	Stiffener ends	75	B, T, PT, FT
	Superstructure shell including framing and stiffeners		
	At curved front	100	T, PT, FT
	Elsewhere	75	B, T, PT, FT

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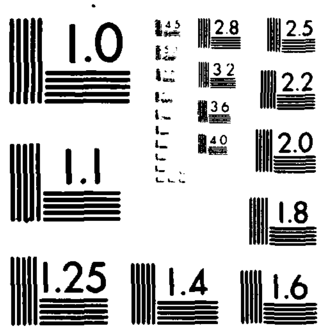

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Table 11-1. Weld Joint Efficiency (Sheet 5 of 5).

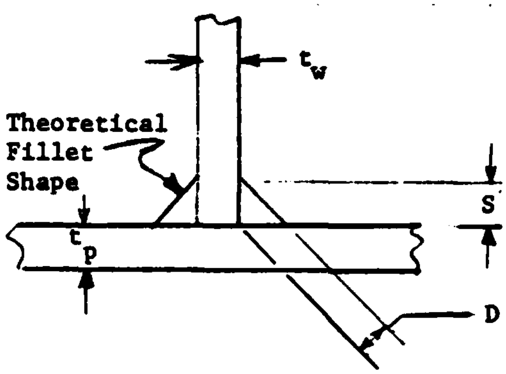
ITEM	CONNECTION	JOINT EFFICIENCY (PERCENT)	JOINT DESIGN CLASSIFICATION
SUPERSTRUCTURE (Continued)	Connections within superstructure		
	Bulkhead periphery		
	Structural	75	T, PT, FT
	Joiner	50	T, PT, FT
	Decks or levels to vertically continuous sides	75	T, PT, FT
	Doors and openings		
	Coaming to plating		
	Bulkheads	75	B, T, PT, FT, C, L
	Shell	100	B, T, PT, FT, C, L
	Stiffener ends to coaming		
	Bulkheads	75	T, PT, FT, L
	Shell	100	T, PT, FT, L
	Framing		
	Flange connections	75	B, T, PT, FT, C, L
	Gussets and chocks	75	B, T, PT, FT, C, L
	Web connections	60	T, PT, FT
	Intercostal sides to decks or levels above 01		
	At curved front	100	T, PT, FT
	Elsewhere	75	T, PT, FT
	Stiffeners to plating and framing		
	At curved front	75	T, PT, FT
	Elsewhere	60	T, PT, FT
WATERJET INLET	Butts and seams	100	B
	Connections to shell	100	B, T, FT
	Framing and fittings	100	B, T, FT

11.6 TEE-JOINT STRENGTH AND EFFICIENCY

The strength and efficiency of continuous double fillet welds and partial penetration tee-joints, regardless of the direction of the applied loading, will be based on the effective longitudinal shear area and the longitudinal shear strength of the filler metal/base metal combination. The effective shear area will be based on the theoretical throat which is the minimum distance from the root of the weld to its face less any reinforcement. Strength calculations for fillet and partial penetration tee-joints are presented below.

11.6.1 FILLET WELDS

FILLET WELDS -- The strength and efficiency of continuous double fillet welded joints will be computed as follows.



Nomenclature

- D = Theoretical throat (in)
- S = Weld size (in)
- t_p = Plate thickness (in)
- t_w = Web thickness (in)
- Q = Longitudinal shear load on weld (lb/in)
- F_{su} = Weld metal shear strength (psi)
- F_{tup} = Plate tensile strength (psi)
- F_{tuw} = Web tensile strength (psi)
- R_1 = Weld longitudinal shear strength (lb/in)

Weld shear area = 2D = 2S sin 45° = 1.414S

Then $R_1 = 1.414SF_{su}$

To determine the required weld size S for an applied load Q, substitute Q for R_1 and solve for S:

$$S = .707Q/F_{su}$$

The computed size will be expressed in 1/16 inch increments and rounded up to the next larger increment except when within 1/64 inch of the next lower increment.

When a design analysis is not performed, the fillet welds will be sized to provide strength capability relative to the parent metal strength using joint efficiency criteria. Except for the special case described below, joint efficiency is defined as follows:

$$\text{Joint Efficiency} = \frac{\text{Fillet weld longitudinal shear strength (lb/in)}}{\text{Ultimate tensile strength of the weaker member (lb/in)}}$$

$$\text{or} \quad \epsilon = \frac{1.414SF_{su}}{t_1 F_{tul}}$$

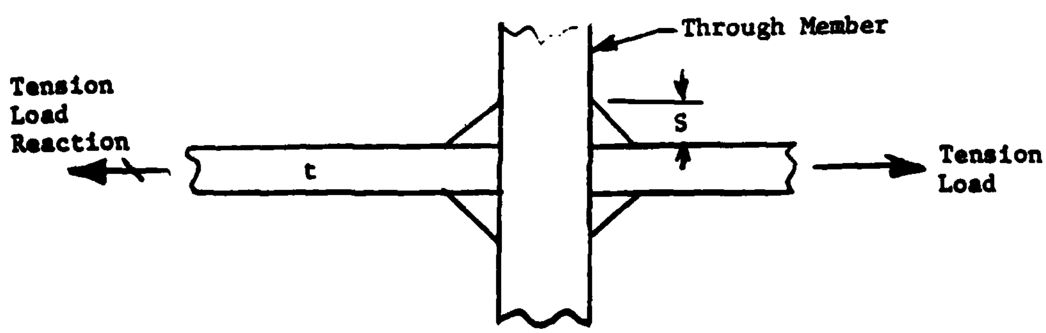
where t_1 and F_{tul} are the thickness and annealed ultimate tensile strength, respectively, of the weaker member. Then,

$$S = .707\epsilon t_1 \ F_{tul}/F_{su}$$

This equation may be used to compute fillet sizes for the various efficiencies specified in Table 11-1. Charts of weld size (and strength) versus weaker member thickness for various joint efficiencies, as developed from the above relation, are presented in Figures 11-21 through 11-24. Using the properties from Table 11-2 for 5456-H116 aluminum alloy and type 5556 filler wire, the equation above becomes:

$$S = 1.088\epsilon t_1$$

From this relation it can be seen that the fillet size becomes large when joining relatively thick materials with 100% efficient joints. Such joints may be required for tension members which are fillet welded to through members as illustrated, although this design will be avoided whenever practicable. In the special case where fillet welds connect thick discontinuous



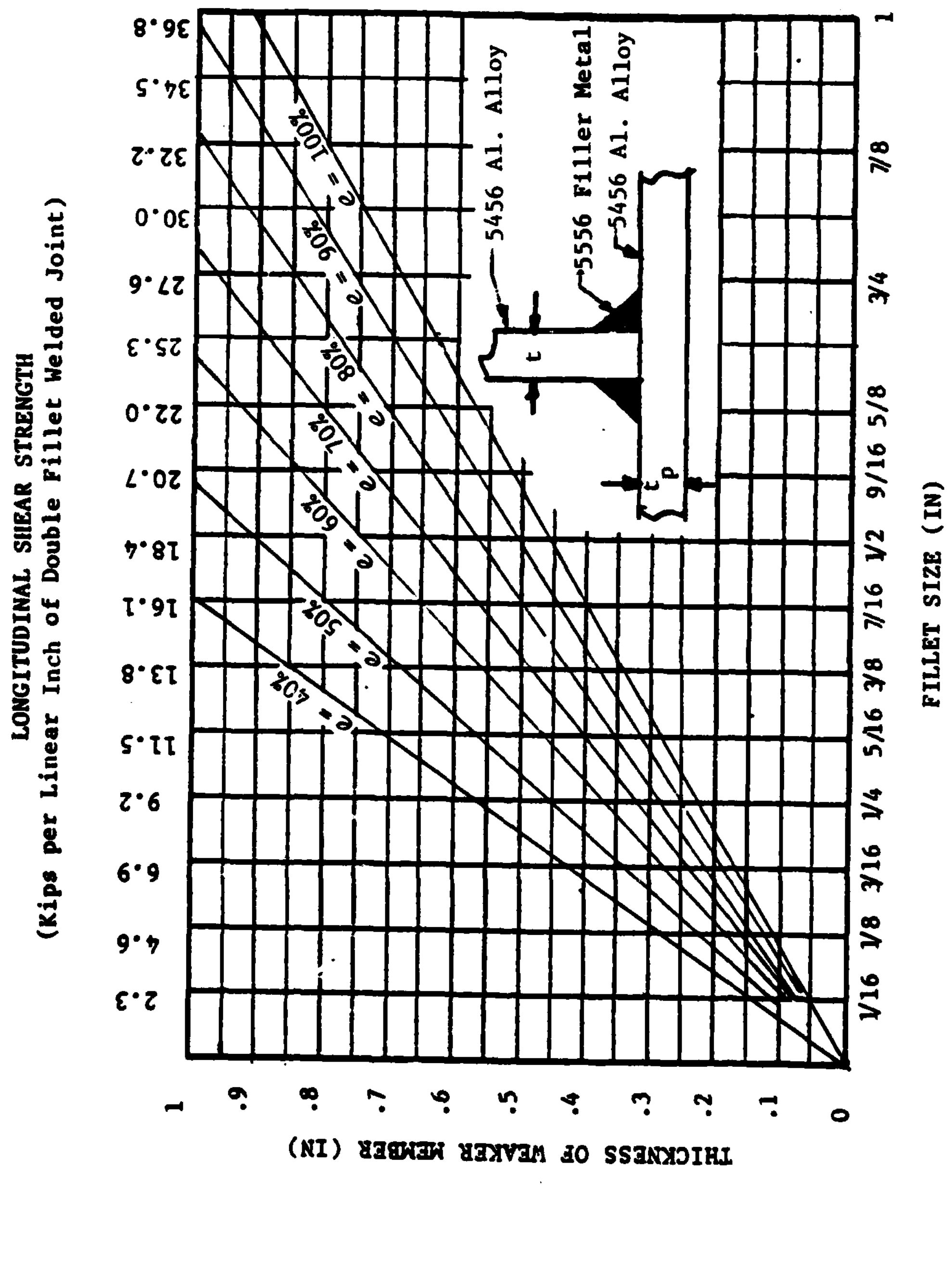


Figure 11-21. Efficiency Chart for Continuous Double Fillet Welded Tee Joints in 5456 Aluminum Alloy Welded with Type 5556 Filler.

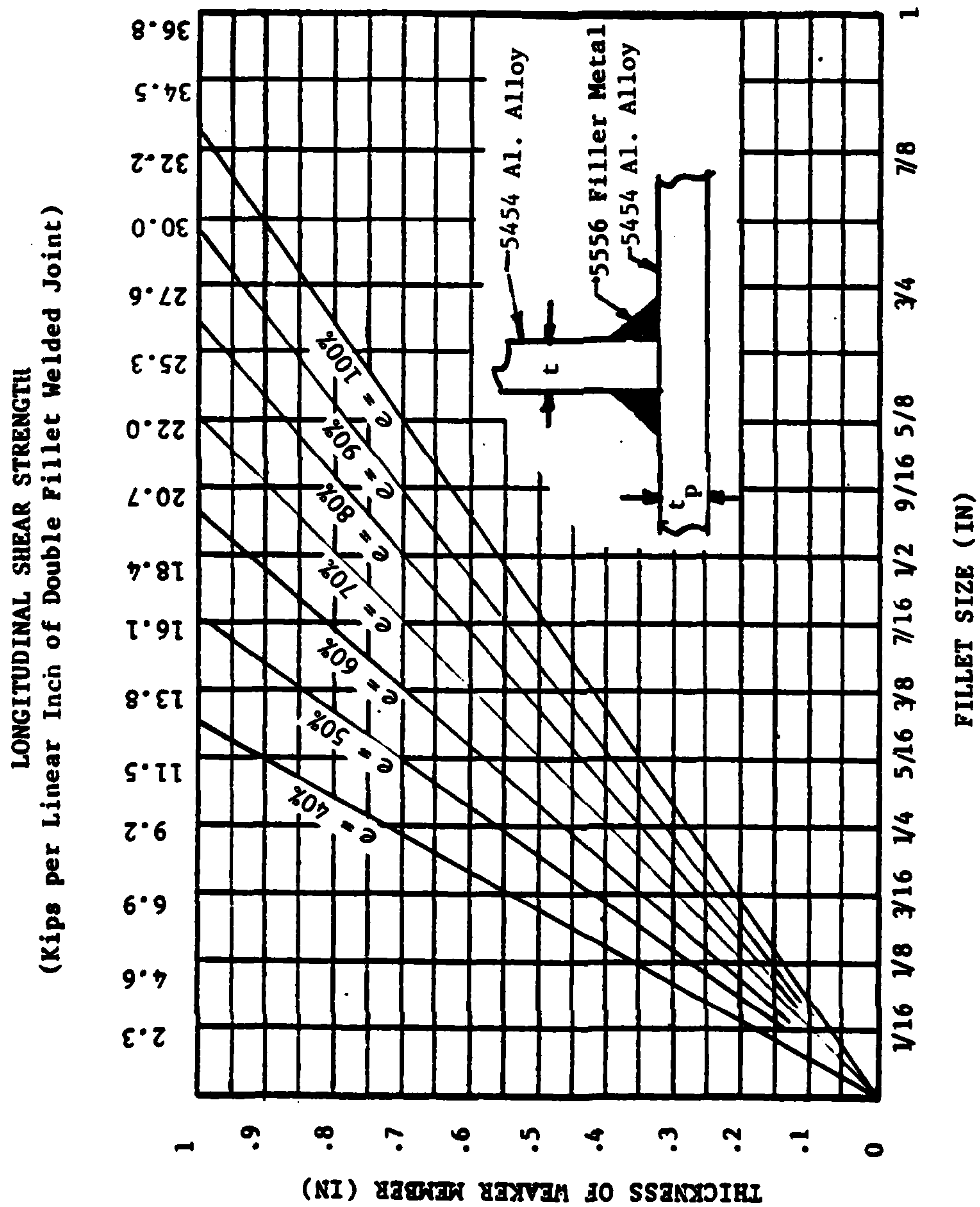


Figure 11-22. Efficiency Chart for Continuous Double Fillet Welded Tee Joints in 5454 Aluminum Alloy Made with Type 5556 Filler.

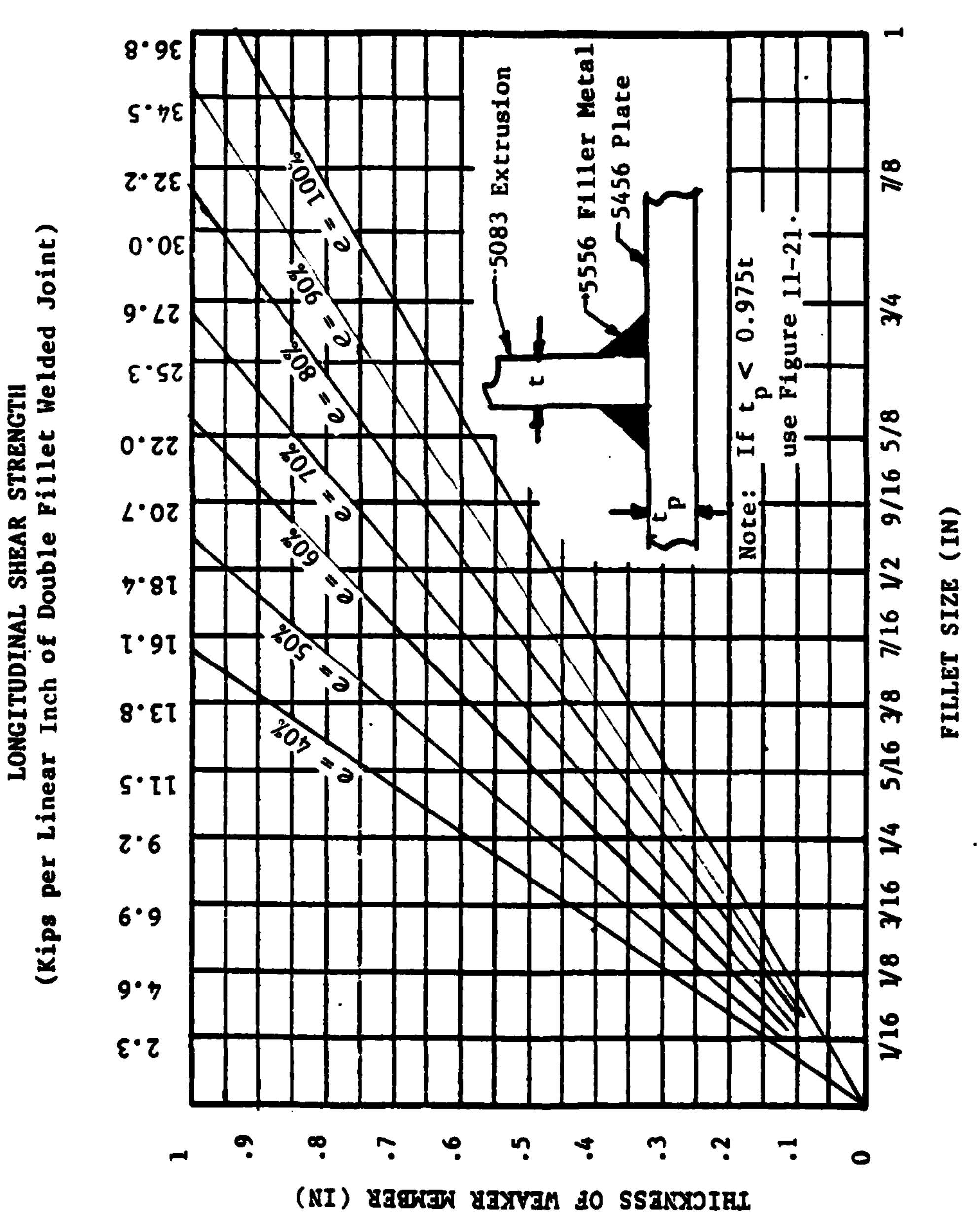


Figure 11-23. Efficiency Chart for Continuous Double Fillet Welded Tee Joints; 5083 Extrusion to 5456 Plate with Type 5556 Filler.

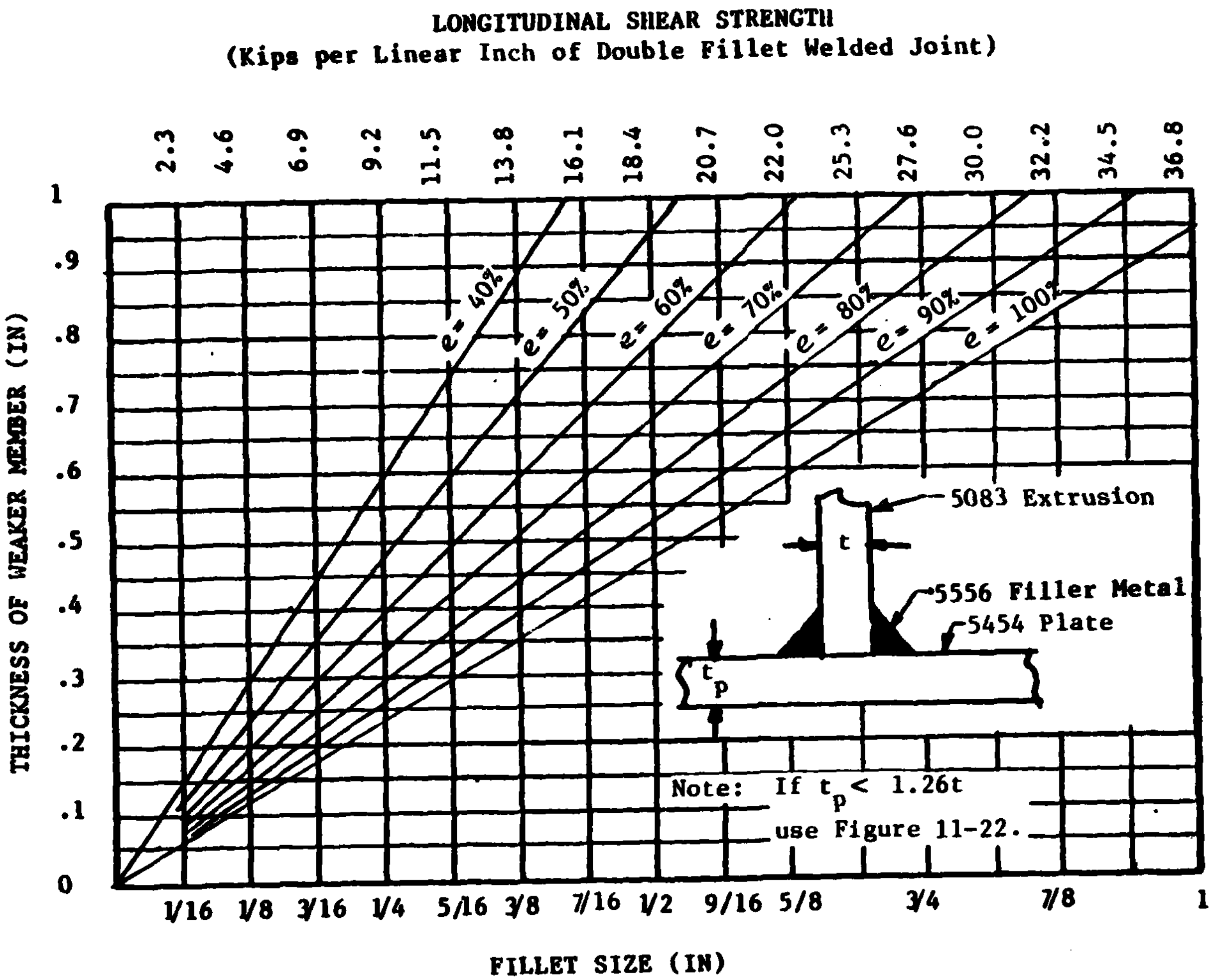


Figure 11-24. Efficiency Chart for Continuous Double Fillet Welded Tee Joints; 5083 Extrusion to 5454 Plate with Type 5556 Filler.

Table 11-2. As-Welded Material Properties

Material Type	Minimum (1)(5) Tensile Strength (ksi)	Minimum (2) Yield Strength (ksi)	Minimum Shear Strength (ksi)
	Base Metals		
5083-H111	39	21	23
5456-H111	40	24	24
5456-H116	40	26	25
5456-H323	40	26	25
5454-H111 (4)	31	16	19
5454-H32 (4)	31	16	19
	Filler Metals		
5556	42	--	26 (3)

(1) As-welded tensile strength properties applicable to the 3KSES.

(2) Yield strength for 0.2 percent offset in a 10-inch gage length across a butt weld.

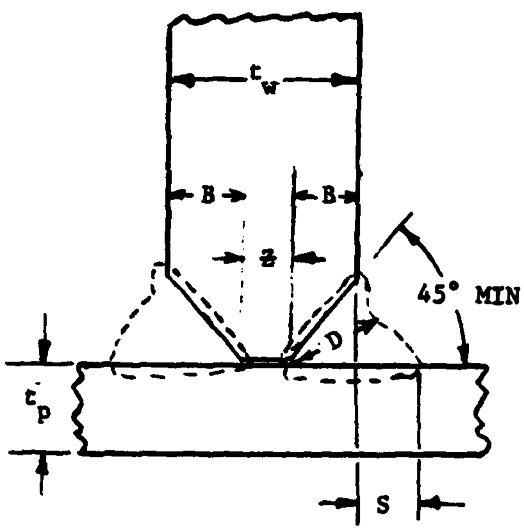
(3) NAVSEA letter PMS304-23/AM:bdb Serial 3134 of 14 June 1979.

(4) Application of 5454 aluminum alloy will be restricted to those areas of the hull structure where exposure to elevated temperatures exceed the limitations of 5456.

(5) The strength properties apply to base materials welded with filler metals of equal or greater strength.

members to opposite sides of a thinner continuous member, the joint design should be based on the structural requirements of the thicker member. If the required fillet size exceeds 1.5 times the thickness of the thinner member a grooved tee joint should be used.

11.6.2 PARTIAL PENETRATION TEE-JOINTS -- The geometrical parameters of partial penetration tee-joints (other than square groove) are computed as follows:



Nomenclature

- D = Theoretical throat (in)
- S = Reinforcing fillet size (in)
- Z = Land dimension (in)
- B = Depth of bevel (in)
- t_p = Plate thickness (in)
- t_w = Web thickness (in)
- t_1 = Thickness of weaker member (t_p or t_w)
- F_{su} = Weld metal shear strength (psi)
- F_{tup} = Plate tensile strength (psi)
- F_{tuw} = Web tensile strength (psi)
- F_{tu1} = Tensile strength of weaker member (psi)
- Q = Longitudinal shear load on weld (lb/in)

Design limitations (from MIL-STD 22):

a. When $Z \leq 3/16$, a full penetration weld will be used.

b. $B_{min} = 1/4$ inch.

c. $S = B$; except $S_{min} = 1/4$ inch and $S_{max} = 1/2$ inch.

Geometry equations:

d. $Z = t_w - 2B$.

e. $B = \begin{Bmatrix} 0.707D & \text{For } D \leq 0.707 \\ \sqrt{D^2 - 0.25} & \text{For } D > 0.707 \end{Bmatrix}$ From MIL-STD-0022.

From a, b, and d above, when the web thickness is less than 11/16 (0.688) inches, a full penetration tee weld is required.

11.6.2.1 Joint Design for Known Loads -- When a design analysis is performed and the loads on the joint are known, the joint parameters will be determined as follows:

$$D = 0.5Q/F_{su}$$

B, S and Z are calculated as in paragraph 11.6.2.

11.6.2.2 Joint Design Based on Joint Efficiency -- When a design analysis is not performed, the joint parameters will be computed as follows to provide the required joint efficiency (ϵ) as specified in Table 11-1:

$$D = 0.5\epsilon t_1 F_{tu1}/F_{su}$$

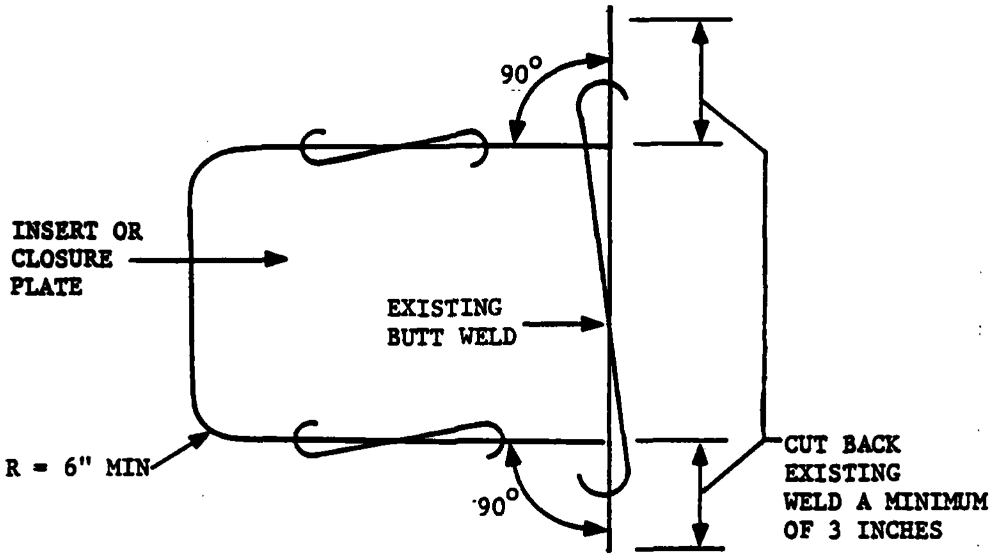
B, S and Z are computed as in paragraph 11.6.2.

11.7 COMPOSITE JOINTS

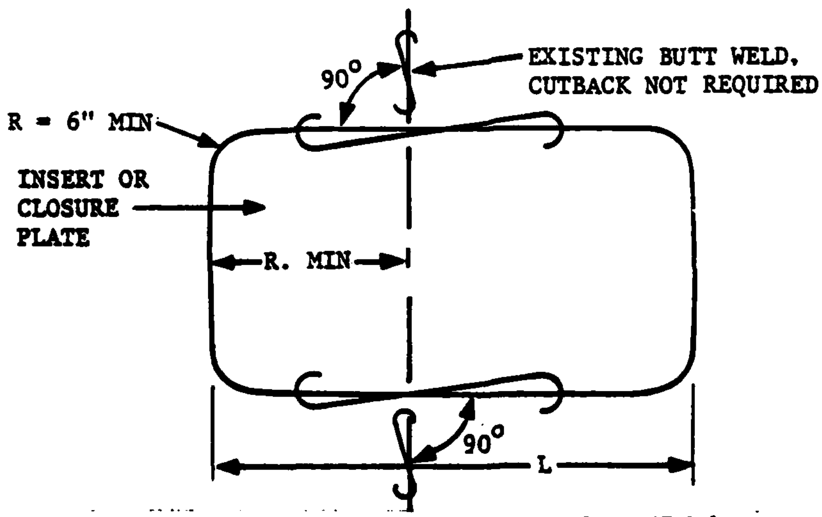
Composite welded-and-riveted joints will not be used without NAVSEA approval.

11.8 INSERTS AND CLOSURE PLATES

Closure plate weld joints will be made with full penetration butt welds. Boundaries of inserts and closure plates will be located between principal framing or bulkheads, and will be at least 3 inches from any of these members. Boundaries of inserts and closure plates will coincide with existing butts or seams whenever practicable. Welding closer than 6 inches to a riveted joint will be avoided. Corners of inserts and closure plates will have a minimum radius of 6 inches except when a boundary coincides with an existing hull longitudinal or transverse butt weld. In the latter instance, the plate boundaries will intersect the butt weld at a 90° angle. (Reference Figure 11-25).



Insert or Closure Plate Boundary Which Coincides With Existing Butt Weld

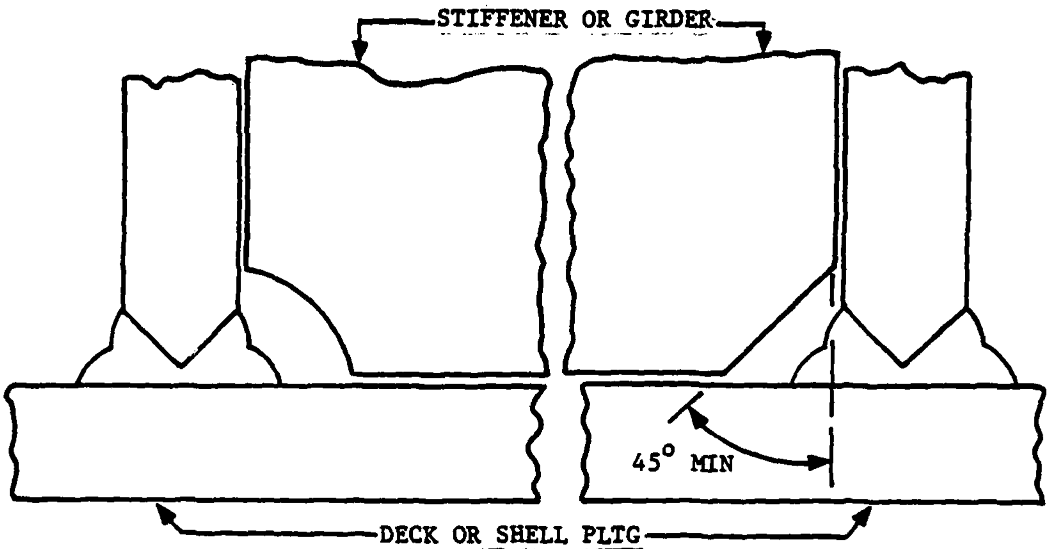


Insert or Closure Plate Which Crosses Existing Butt Weld

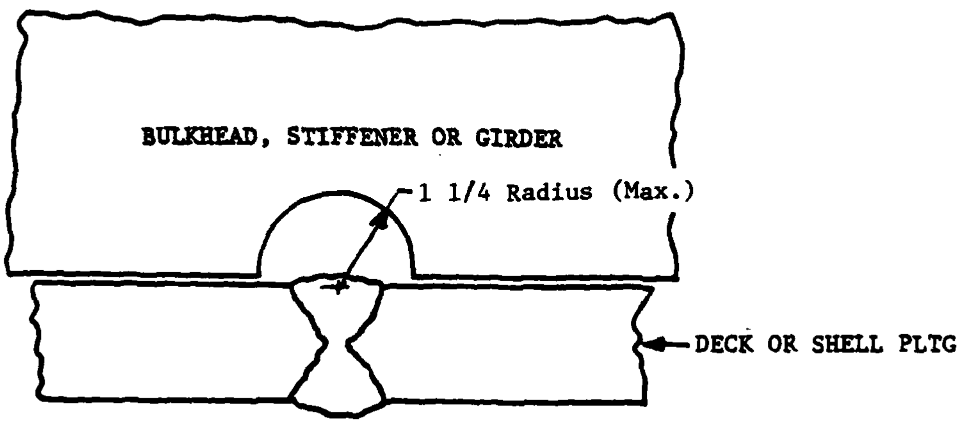
Figure 11-25. Insert or Closure Plate Requirements Related to Existing Butt Welds.

11.9 PERMANENT SNIPES

Where water or oil tightness is not a consideration, use of permanent corner or scallop snipes in members joined to plating will be permitted to provide accessibility for welding and for vents and drains. The maximum allowable size for snipes will be determined by design and stress considerations. Typical permanent snipes are shown in Figure 11-26. The relief, keyhole-type snipe shown in Figure 11-27 may be used as an alternate for the conventional permanent corner snipe shown in Figure 11-26.



Permanent Corner Snipes in Connecting Member Which Intersects Two or More Other Members



Permanent Scallop Snipe in Connecting Structural Member Being Crossed By a Butt Weld

Figure 11-26. Typical Permanent Snipes

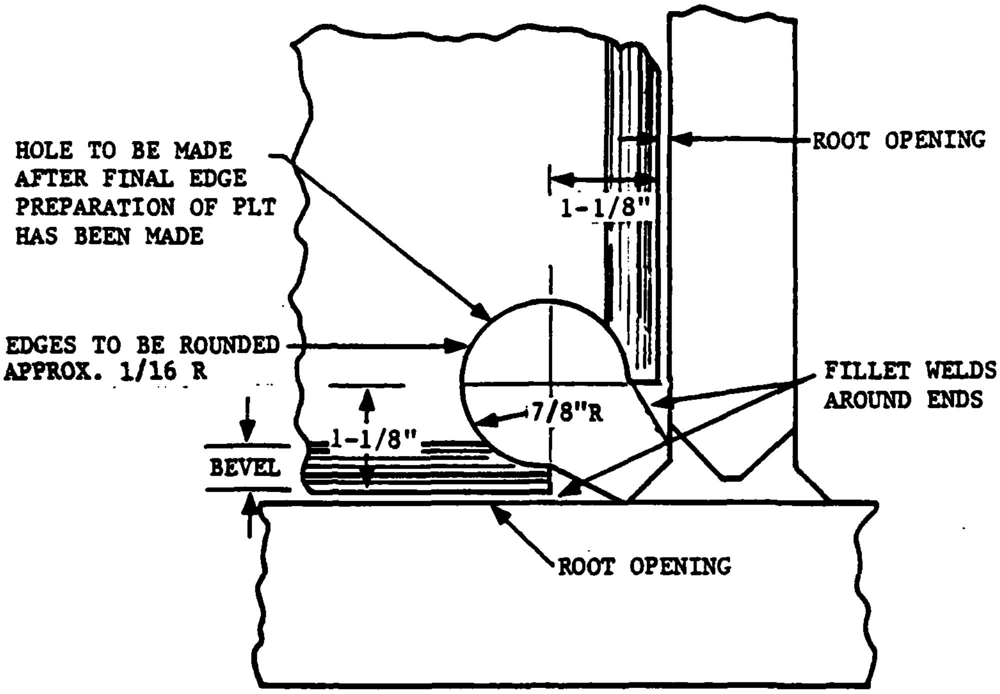


Figure 11-27. Alternate Drain or Vent Opening for Tank Structure

15 / FATIGUE AND FRACTURE CONTROL

15.1 SCOPE

This section contains guidance for the identification of fatigue sensitive structures and requirements for workmanship and treatment of welded joints to improve the resistance to fatigue crack initiation and propagation.

15.2 GENERAL

Fatigue crack initiation in welded aluminum structure can be minimized by appropriate design features and fabrication techniques, and controlled by an effective in-service hull surveillance program.

15.3 FATIGUE DESIGN CONSIDERATIONS

The hull structure will be designed as specified in Report No. T23100001, 3KSES Hull Structure Specification. In the execution of the design the following considerations are essential.

15.3.1 ACCESSIBILITY -- Provision of adequate accessibility to all parts of the structure to permit the effective use of production welding, cutting, and chipping equipment is mandatory.

In the design of structural details the following features will be considered to improve accessibility.

a. Locate butts and seams in accessible areas; align seams when possible.

b. Produce designs conducive to work sequencing which permits production welding of subassemblies and finishing of joints as early as practicable before assembly.

c. Provide sufficient detailing in order to plan and complete all cuts and penetrations in optimum sequence before assembly. Cuts made out-of-sequence may entail poor accessibility conducive to undetected notches, rough cuts, inadequate rounding of corners and other imperfections susceptible to crack initiation.

d. Avoid chocks in tight-fit spaces.

15.3.2 STRUCTURAL DETAILING -- Consideration of fatigue susceptibility in the detail design stages is of major importance. In addition to the general requirements specified in the Hull Structure Specification, the design should, wherever practicable, encompass the following guidelines:

a. Design structural details which eliminate hard spots, knife edges, and awkward welds.

b. Avoid welding by using formed shapes wherever practicable.

c. Eliminate stress-raisers in heat affected zones.

d. Do not terminate ends of stiffeners on unsupported plate.

e. Reflect simple and common sense producibility in the detail design.

f. Avoid abrupt changes in cross-section.

g. Avoid penetrations in the unsupported area of a bulkhead or deck panel.

h. Preserve continuity throughout the structure.

i. Taper the thicker of two butt-welded plates whenever the difference is more than 1/8 inch.

j. Compensate with inserts rather than doublers.

k. Stagger butt-welds at stiffeners from those in plating at main erection joints.

15.4 DESIGNATED FATIGUE SENSITIVE STRUCTURES

15.4.1 GENERAL -- Although strict attention to proper detail design and fabrication practice minimizes the probability of fatigue damage, some areas of the structure may be subjected to significant stress reversals that increase susceptibility to fatigue crack initiation. Examples of such areas are design details where reductions in fatigue stress concentration by weld treatment are more desirable than other solutions; e.g., overall material thickness increases. Structures in which this situation exists may be designated by Engineering as fatigue sensitive. Structures specifically designated fatigue sensitive, as described below in paragraph 15.4.2, will be subjected to the inspection requirements for critical structure specified in Section 6 of this document. Beyond the increased scope of inspection required, additional and more stringent fabrication requirements will be imposed on designated fatigue sensitive structure as specified in paragraph 15.5, below.

15.4.2 CLASSIFICATION -- Fatigue sensitive structures will be classified, according to level of criticality, as follows:

Class A: Areas of primary hull structure which are predicted to be susceptible to fatigue crack initiation.

Class B: Areas of primary or secondary hull structure which may be susceptible to fatigue crack initiation, but are considered less critical than Class A, above.

Fatigue sensitive structures will be designated "CR/FSA" or "CR/FSB" for Class A or Class B, respectively, on the applicable engineering drawings. When either of these classifications is assigned, the extent of the weld or structural area classified as CR/FSA or CR/FSB will be clearly defined.

15.5 FABRICATION AND ACCEPTANCE STANDARDS FOR FATIGUE SENSITIVE STRUCTURES

Requirements applicable to each class of structure designated fatigue sensitive, CR/FSA and CR/FSB, are described below. Findings from the Structural Panel and Element Testing Program are reflected in these requirements.

15.5.1 FABRICATION REQUIREMENTS FOR CLASS A FATIGUE SENSITIVE STRUCTURES -- CR/FSA structure requirements for workmanship, including contouring, the installation of doublers, and the possible use of peening will be as specified below. Contouring of butt welds may be performed either before or after the required radiographic inspection has been performed. Peening, if specifically required, will be performed after the required radiographic inspection has been completed and any defective welds have been repaired.

15.5.1.1 Workmanship -- In addition to the standards set forth in Sections 8 and 14 of this document, the following requirements will be applicable:

a. Butt weld reinforcements will be contoured to achieve a gradual transition from the peak of the reinforcement to the base metal with no visible breaks or steps in the contour. (As an option to contouring, butt welds may be machined flush with the base metal.) Fillet weld reinforcements will be contoured to remove convexity in excess

of 1/32 inch and to achieve a smooth transition from the face of the weld to the base metal.

Any mechanical means such as rotary filing, machining, shaving or sanding will be acceptable for contouring weld reinforcements providing the following conditions are met:

(1) The process will be performed by qualified personnel using approved procedures.

(2) The finished contour will blend smoothly with no notches, scratches, indentations, bumps, protrusions, steps or other stress raisers.

(3) The process will be controlled so that the base metal temperature does not exceed 200 degrees F.

(4) There will be no imbedding of foreign particles in the weldment.

(5) Depressions will be approximately ellipsoidal in surface shape and sinusoidal in cross-section. Where the depth of the adjacent base metal removed exceeds that specified in paragraph 14.5.4.1 of this document, the thickness will be restored using approved repair procedures.

b. Tool and inadvertent marks will be removed by blending into the surrounding metal using the contouring methods and complying with conditions specified in "a" above.

c. Exposed edges and corners will be broken to remove sharpness and/or burrs. Breaking of edges and corners will be performed in compliance with the methods and conditions specified above in "a".

d. The welding sequence will be such that fatigue sensitive structure has priority over other structure in order to minimize distortion and residual stress buildup.

15.5.1.2 Doubler Reinforcement Over Welds -- Doublers may be installed over butt welds designated fatigue sensitive when specifically authorized by Engineering to improve the fatigue life of the joint by the reduction of stresses. Each doubler installation so authorized will meet the following requirements:

a. Doubler design will be based on the results of the 3KSES Structural Panel and Element Test Program.

b. Doublers will be installed by qualified personnel using approved procedures.

c. Installed doublers will be inspected to the same criteria as the basic joint on which the doubler is installed.

15.5.1.3 Peening -- Brush or rotary flapper peening only will be performed, when specifically designated by Engineering or the Material Review Board for each application, to induce residual compressive stresses in the surfaces of the weld and adjacent heat affected zones to improve the resistance to fatigue cracking. Peening will be accomplished using an approved method in compliance with the following:

a. Peening will be performed by qualified personnel using approved procedures.

b. Peening will be accomplished to provide complete coverage of the weld reinforcement and adjacent heat affected zones on both sides and both faces of the joint over the full length specified. Every portion of the specified surface area will show evidence of plastic flow to indicate coverage and obliteration of the original surface finish.

c. Weld reinforcements will be contoured as required above in paragraph 15.5.1.1a. prior to peening.

d. Peening intensity will be 0.004 to 0.008-inch Almen A arc height.

e. In-process inspection and final visual inspection will be performed to assure adherence to procedures and to assure that complete coverage of the specified areas has been achieved.

15.5.2 FABRICATION REQUIREMENTS FOR CLASS B FATIGUE SENSITIVE STRUCTURES -- CR/FSB structures will comply with the workmanship requirements of Section 14 of this document and the following:

a. Tool and inadvertent marks will be removed from the weld reinforcements and/or base metal by blending into the surrounding material. General contouring or blending of the weld reinforcement is not required. Blending of marks will be accomplished using the methods and complying with the conditions specified in paragraph 15.5.1.1a, above.

b. Exposed edges and corners will be broken to remove sharpness and/or burrs. Breaking of edges and corners will be performed in compliance with the methods and conditions specified above in paragraph 15.5.1.1a.

c. The welding sequence will be such that fatigue sensitive structure has priority over other structure in order to minimize distortion and residual stress buildup.

15.5.3 ACCEPTANCE STANDARDS FOR CLASS A FATIGUE SENSITIVE STRUCTURES -- CR/FSA structures will comply with the requirements of paragraph 15.5.1 above and the Class 1 visual and radiographic standards specified in Section 8 of this document.

15.5.4 ACCEPTANCE STANDARDS FOR CLASS B FATIGUE SENSITIVE STRUCTURES -- CR/FSB structures will comply with the requirements of paragraph 15.5.2 above, the Class 1 visual inspection standards of paragraph 8.4 of this document and the Class 3 radiographic standards of paragraph 8.6 of this document.

12 / ERECTION REQUIREMENTS

12.1 SCOPE

This section contains fabrication and erection requirements for use on the 3KSES. The requirements contained herein are pertinent to aluminum alloys and consider the relatively high coefficients of thermal expansion which are characteristic of these alloys. The information contained in these erection requirements is representative of experience and data accumulated to date and from ongoing structure fabrication efforts.

12.2 ASSEMBLY AND ERECTION

12.2.1 GENERAL -- The concept for fabrication and erection of the hull structure is presented in the Production Plan (TPP001). Paragraph 3.2 of the Production Plan describes and illustrates the build-up of stiffened panels and the addition of transverse frames, the assembly of stiffened panels into major assemblies and the assembly erection schedule. General requirements for fitting and welding a typical assembly are presented in the following paragraphs.

The primary concern for fabrication of welded aluminum structure is the control of distortion and weld imperfections. General principles to minimize the effects of distortion are as follows:

a. Assemble elements such that assembly and welding will be balanced and progress symmetrically.

b. Except for specific details, restrain shrinkage by force using clamps, jigs and fixtures. Where possible the application of restraints should be sequenced to minimize preloading the work piece.

c. Deposit weld metal rapidly, at uniform speed, to form the smallest possible joint which is acceptable for strength requirements.

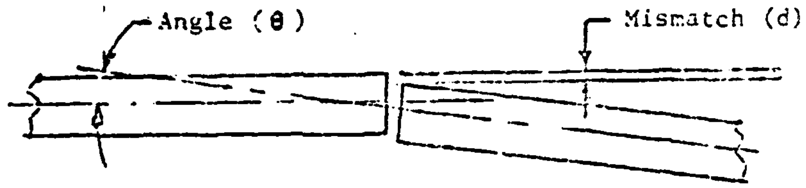
d. Minimize the number of weld passes to avoid a build up of shrinkage effects.

e. Plan for shrinkage by pre-setting and pre-bending the work piece.

f. Use automatic welding equipment for greater consistency and faster welding.

g. Take advantage of allowable joint fit-up tolerances of complex details to minimize "force fit" with accompanying distortions and induced stresses.

12.2.1.2 Fit-up Tolerances Before Welding -- Butt joint fit-up tolerances include thickness offset mismatch between plates, angular misalignment, and joint root opening. Guideline tolerances for butt joint offset mismatch and angular misalignment before welding are presented in Figure 12-1; however, joint fit up tolerances will be such as to assure compliance with the alignment tolerances after welding as specified below in paragraph 12.5.1. Butt joint root openings will be as defined in Section 11 of this document. Fillet and tee joint connection requirements will also be as specified in Section 11.



Thickness (T)	Allowable Mismatch (d)	Allowable Angular Misalignment (θ)
Less than 3/8"	1/16"	3°
3/8" & above	1/8"	3°

Figure 12-1. Allowable Butt Joint Mismatch and Misalignment *Before Welding.*

12.2.1.2 Shrinkage Allowances -- Allowance will be made for shrinkage of sub-assemblies to meet the tolerances specified in paragraph 12.5 below. Sub-assemblies will be provided with excess material at the outer boundaries, as required, to compensate for weld shrinkage. General allowances for shrinkage for aluminum are presented in Figure 12-2. Factors affecting weld shrinkage such as fixturing, joint restraint, welding process, sequence of welding, and size of welds (volume) will be considered.

12.2.2 MAJOR ASSEMBLY FABRICATION--Flat stiffened panels for decks and bulkheads will be fabricated using the automatic welding equipment described in paragraph 13.9. The vacuum chuck will clamp the plate surface to the platen and provide constraint against out of plane distortion during welding operations.Also the lateral restraint, or traction, provided by friction between the plate and platen surfaces will lessen in-plane distortion. The vacuum chuck will be used during assembly and welding of panel plates and attachment of stiffeners and frames as described below.

PLATE THICKNESS	SHRINKAGE ALLOWANCE
BUTT WELDS	
TRANSVERSE TO WELD	
To 3/16 inch thick	1/32 inch shrinkage
3/16 to 1/2 inch thick	1/16 inch shrinkage
Over 1/2 inch thick	1/16 to 3/16 inch shrinkage
LONGITUDINAL TO WELD	
1/4 inch thick and less	1/8 to 1/4 inch in 10 feet
1/4 to 3/8 inch thick	1/16 to 3/16 inch in 10 feet
3/8 to 1/2 inch thick	1/16 to 1/8 inch in 10 feet
Over 1/2 inch thick	1/16 inch in 10 feet
TRANSVERSE TO DOUBLE FILLET WELDS	
1/4 inch thick and less	1/32 to 1/16 inch per stiffener
1/4 to 3/8 inch thick	1/16 inch per stiffener
3/8 to 1/2 inch thick	1/32 inch per stiffener
Over 1/2 inch thick	No allowance

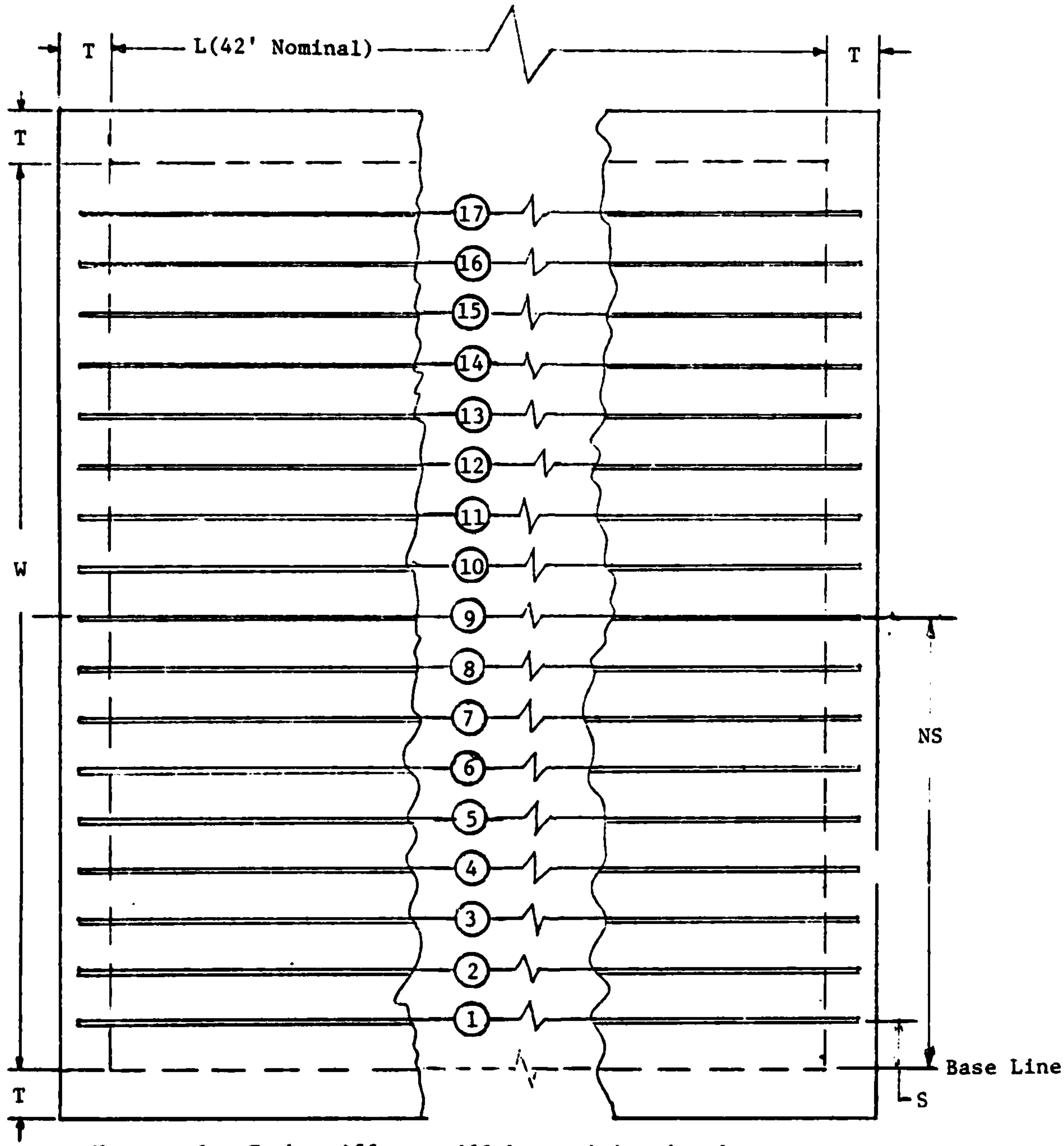
Figure 12-2. General Weld Shrinkage Allowances for Aluminum.

12.2.2.1 Panel Plate Assembly and Weld Sequence -- Longitudinal bulkhead and deck panels, including trim allowances, will vary from approximately 10 ft to 17 feet in width and up to 46 feet in length; maximum size for transverse bulkhead panels is will be 10 X 17 feet. Panels with a 10-foot (or less) dimension will generally be made from a single plate; wider panels will be assembled with a longitudinal butt weld. Where plates of dissimilar thicknesses are joined, a perforated liner plate will be placed on the vacuum chuck under the thinner plate to provide alignment of the upper surface of the adjoining plates. After joint preparation the adjoining plates will be fit in place, clamped to the table with the vacuum system, and the butt joint welded from end to end with the automatic welding machine. Where the joint requires welding from two sides, the opposite side weld will be made after the stiffeners and frames are attached so accessibility can be provided without imposing handling stresses on the uncompleted butt joint.

12.2.2.2 Stiffener to Panel Welding Sequence -- Prior to removing the plate from the vacuum chuck, the stiffeners will be fillet welded using the sequence illustrated in Figure 12-3. Each stiffener will be welded from end-to-end using tandem welding heads to make the double fillet joint. Approximately 18 inches from the trim line on each end will be left unwelded to facilitate subsequent fit-up to adjacent panels. Dimensional control of stiffener spacing will be assured by referencing the location of each stiffener to a common base line.

12.2.2.3 Frame to Panel Welding Sequence -- The longitudinal tee shown in Figure 12-4 will be positioned parallel to the stiffeners and fillet welded to the plate. The transverse frame tees will then be fitted and welded, using semiautomatic equipment, with the weld sequences illustrated in Figures 12-4 through 12-6. This sequence has been found to minimize the formation of cracks in the longitudinal tee-to-frame tee joints subsequent to welding.

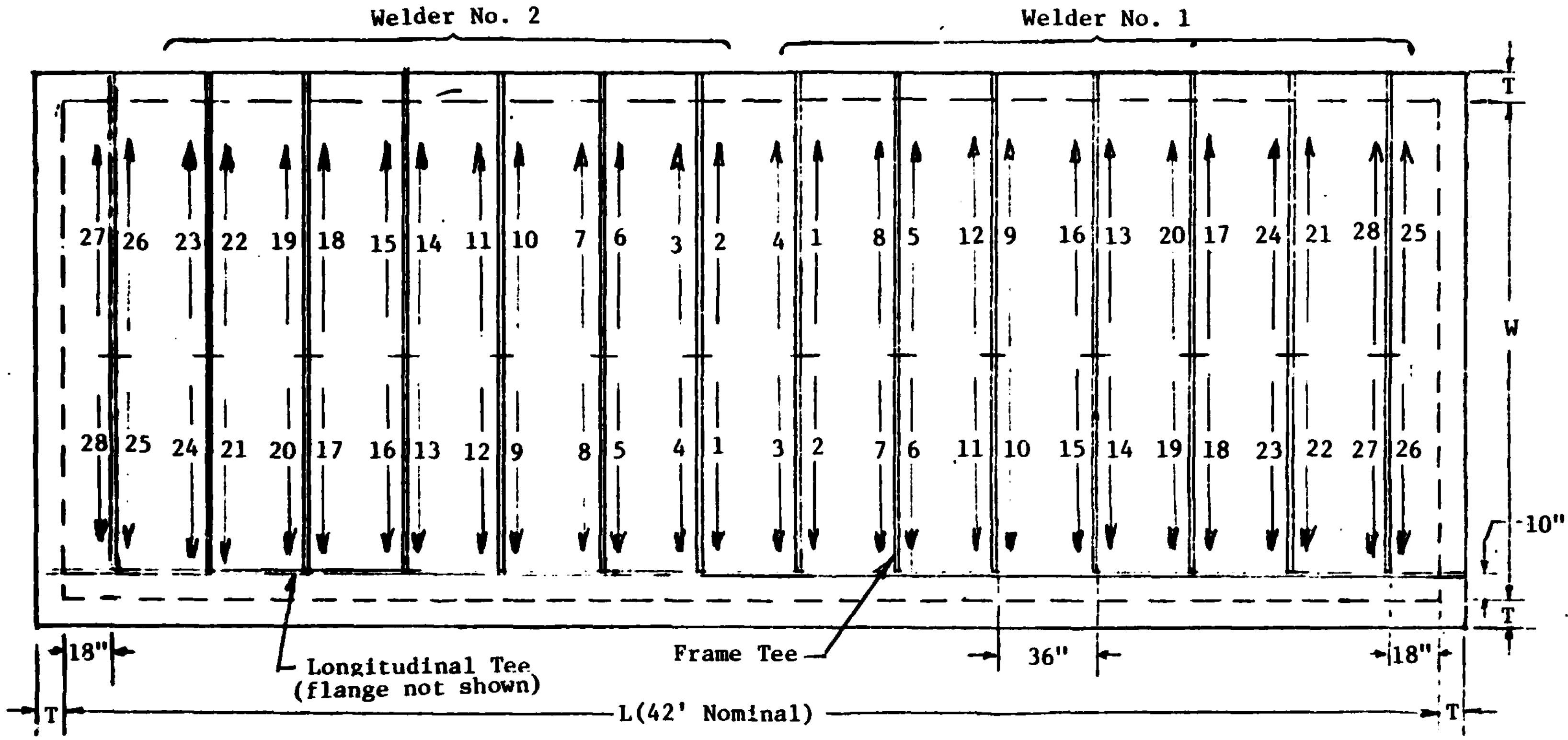
The transverse frames will be extruded tee members except at the transverse bulkhead intersections. Fabricated offset tee's, used at transverse



Notes: 1. Each stiffener will be positioned and welded relative to the baseline.

2. T = trim allowance; S = stiffener spacing; L(length) and W(width) are panel net dimensions. N = Number of spaces from baseline.

Figure 12-3. Welding Sequence - Stiffeners to Deck Panels.

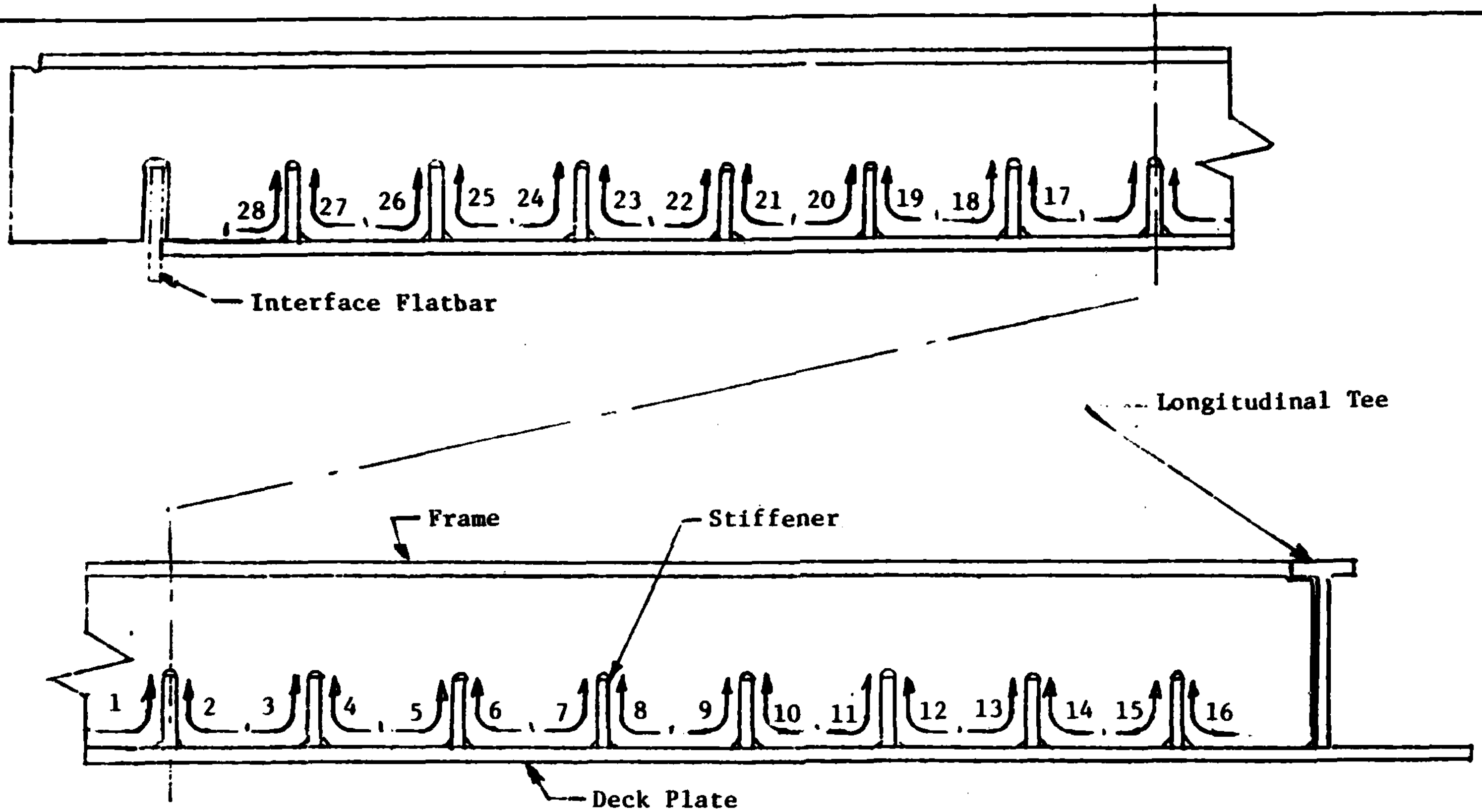


Notes: 1. Frame flanges and longitudinal stiffeners are not shown for clarity.

2. L (length) and W (Width) are net dimensions; T = trim allowance.

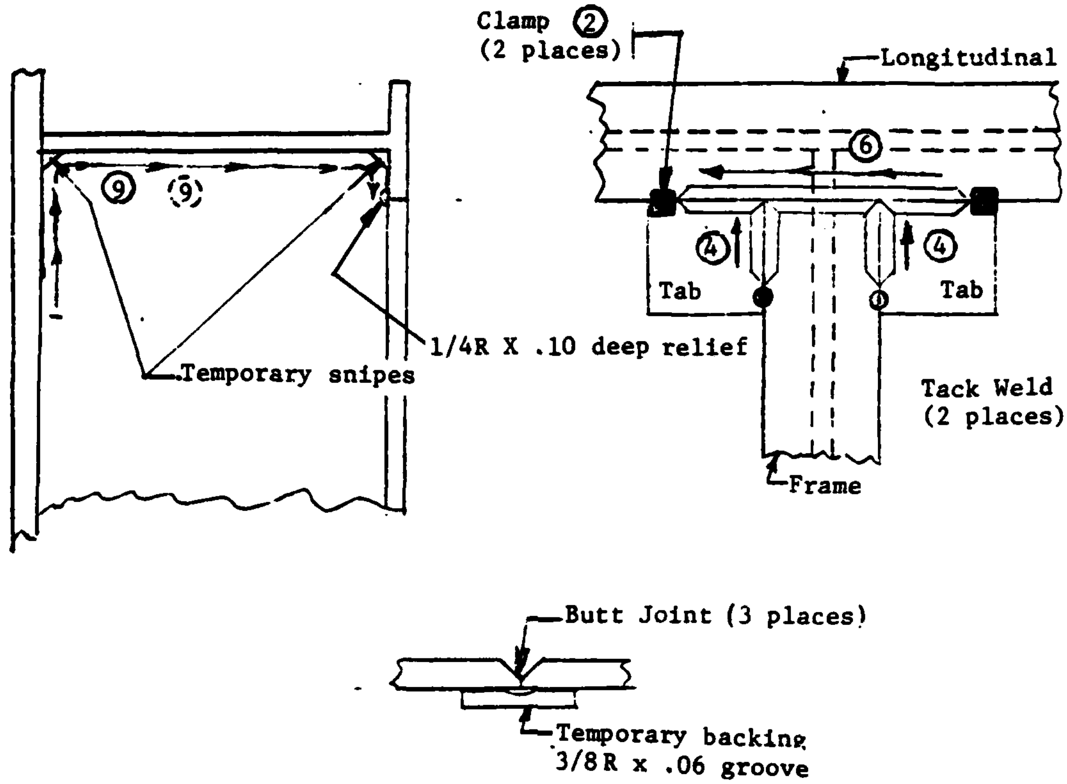
3. Detail weld sequence for frame-to-longitudinal tee and plate attachment shown in Figure 12-5.

Figure 12-4. Welding Sequence for Two Welders - Frames to Stiffened Deck Panels.



Note: Weld longitudinal tee to frame per Figure 12-6 prior to welding across stiffeners in sequence indicated.

Figure 12-5. Detail Welding Sequence - Frame to Stiffened Deck Panel.



1. Make temporary snipes and radiused relief in frame web prior to joint fit-up.
2. Tack weld and clamp start and stop tabs.
3. Make bevel grooves for 3 butt welds.
4. Make welds on tab/frame joints into the relief for the frame/longitudinal butt joint.
5. Grind or rotary file weld in relief as required prior to making final butt weld.
6. Make final frame/longitudinal butt weld using start and stop tabs.
7. Remove tabs with plasma arc or saw.
8. Clean up root bead and excess weld; radius corners as required
9. Make fillet welds on near and far side in directions as shown.

Figure 12-6. Joint Preparation and Welding Technique for Tee-to-Tee Intersections.

bulkhead intersections, will be attached using the sequence in Figure 12-4; chocks between deck stiffeners and the offset tee flange will be subsequently welded.

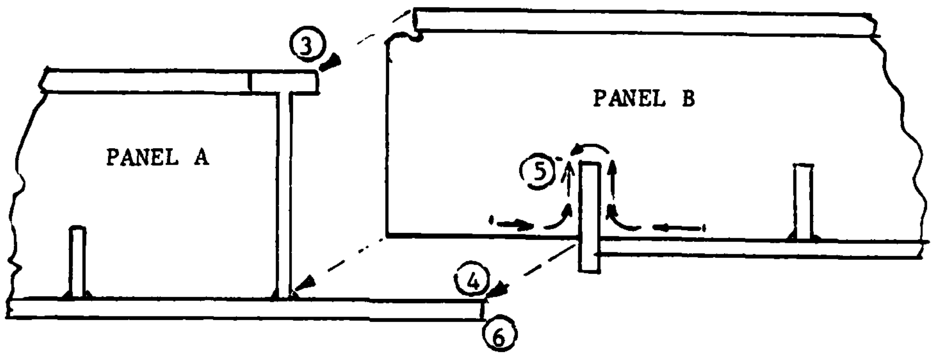
12.2.2.4 Interface Flatbar to Panel Welding Sequence -- The stiffened panel will be removed from the vacuum chuck for attachment of the interface flatbar and welding the underside of the plate seam(if required). The interface flatbar will be fillet welded to the plate only starting at the center and progressing toward each end. On the frame side, the fillet weld will be stopped approximately three inches from each side of the frame to facilitate subsequent fitting of the frame end joint.

12.2.3 PANEL TO PANEL FIT-UP AND WELD SEQUENCE -- The stiffened panel elements which form the decks of major erection assemblies will be assembled and welded prior to attachment of longitudinal and transverse bulkheads. Figure 12-7 depicts the cross section of a typical panel-to-panel joint and presents the welding sequence at each frame. The welding willstart at the center frame(s) and progress toward each end. The underside plate to interface fillet will be welded last from the center to each end.

12.2.4 BULKHEAD TO DECK ASSEMBLY -- After the deck panel for each assembly unit has been fabricated, the longitudinal and transverse bulkheads will be assembled and welded.

12.2.4.1 Longitudinal Bulkheads -- The longitudinal bulkheads will be erected initially and tack welded into position. Welding of each bulkhead assembly to deck assembly will start in the center and progress toward each end. The geometry and welding sequence at a typical cross section is illustrated in Figure 12-8. The longitudinal bulkheads will be terminated approximately 10 inches short of the net deck transverse edge to provide transverse access during hull erection; an insert will be installed while completing the erection joint.

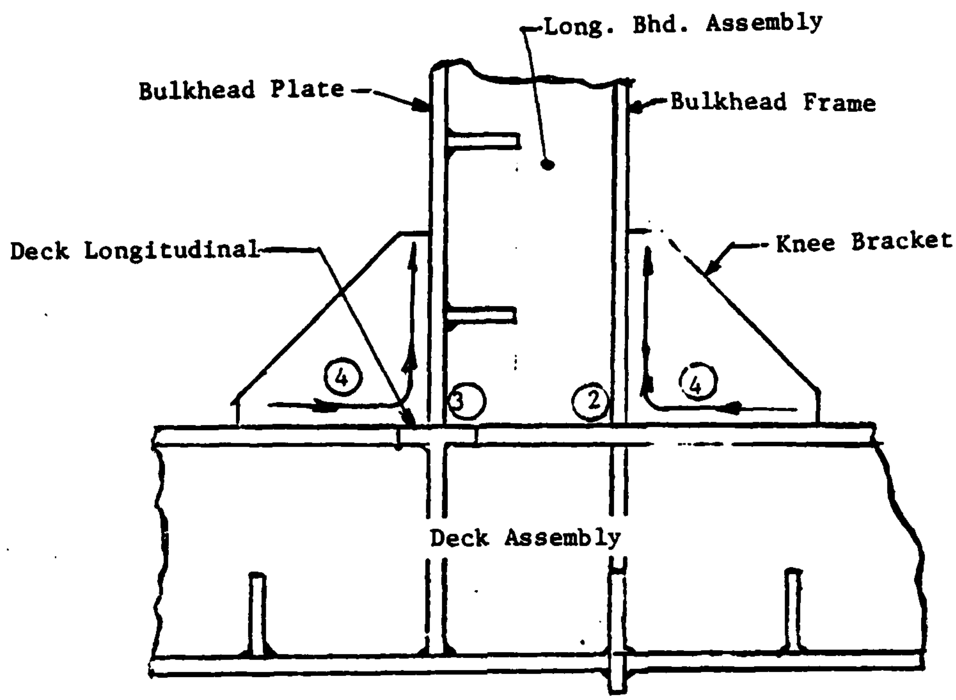
12.4.2.2 Transverse Bulkheads -- These bulkheads will consist of vertically stiffened panels between major longitudinal bulkheads.



Assembly and Welding Sequence

1. Trim excess plating from Panel A and trim frame ends on Panel B to fit.
2. Bring panels into coincidence.
3. Weld interface tee joint using technique shown in Figure 12-6. (See paragraph 12.2.3)
4. Fillet weld the deck frame side of Panel A to the interface flat bar. (See paragraph 12.2.3)
5. Fillet weld Panel B frames to interface flatbar and close out unwelded ends of flatbar fillets adjacent ot deck frames.
6. Weld underside fillets to interface flatbar progressing from center towards each end.

Figure 12-7. Assembly and Welding Sequence for Stiffened Deck Panels.



Assembly and Welding Sequence

1. Erect the bulkhead, brace and tackweld in position.

(2) Fillet weld the bulkhead frame cap and web to deck plate progressing toward the bulkhead plate on each side of the web.

(3) Fillet weld bulkhead plate to deck longitudinal flange between frames with completed end welds.

(4) Fillet weld knee brackets to frames.

Figure 12-8. Erection and Welding Sequence - Longitudinal Bulkhead Assembly to Deck Assembly.

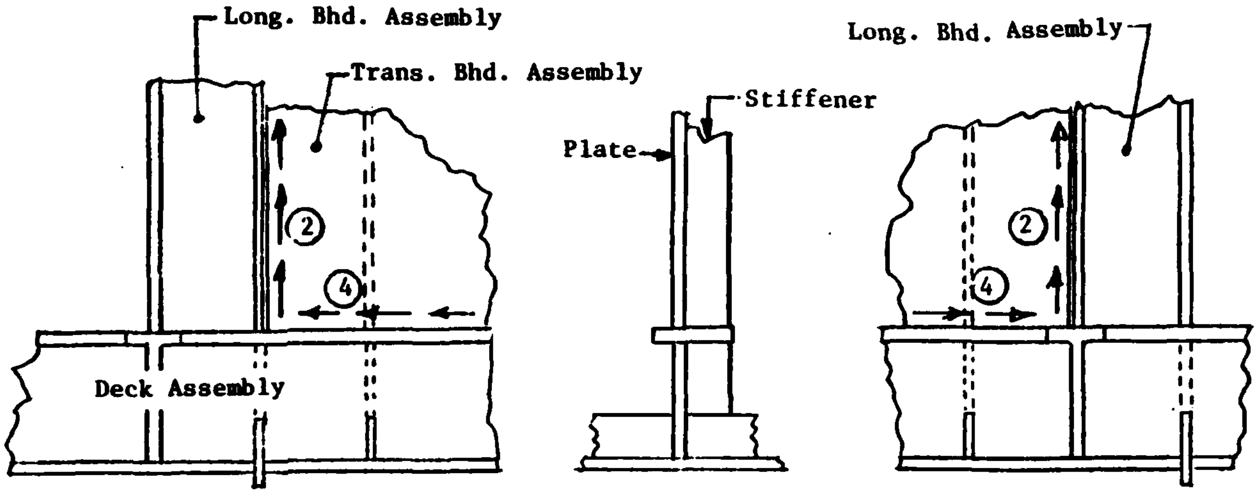
The transverse bulkhead sections will be trimmed to net dimensions, erected, fit and tack welded in position. The arrangement of the bulkhead assembly is illustrated in Figure 12-9. Welding will start with the vertical fillets on each end of the transverse bulkhead followed by welding the deck intersection fillet welds as described in Figure 12-9. Upon completion of welding the remaining transverse bulkheads, the adjacent end of the assembly unit will be trimmed to net dimensions. The assembly will then be braced for transportation to the ship erection facility.

12.2.2.6 Other Major Assembly Fabrication--Paragraphs 12.2.2.1 through 12.2.2.5 above describe the assembly and welding sequences for a major centerbody erection unit above the third deck. The boundaries of these and other major assemblies are described in Section 3 of the Production Plan (TPP001). The other assemblies will be assembled, erected and welded using techniques similar to those described in paragraphs 12.2.2.1 through 12.2.2.5 above.

12.2.3 WELD SEQUENCE FOR MAJOR ASSEMBLY ERECTION JOINTS -- The assembly sequence of the major units at the building site is described and illustrated in Section 1 of the Production Plan (TPP001). After required trimming to net dimension and fit-up, the first welds made will be the transverse butts joining separate centerbody assemblies. Welding will progress simultaneously to port and starboard from the centerline using backstep sequences. The following sequence will be used to complete the connection of two units:

1. Weld transverse deck butt joints
2. Weld deck stiffener inserts
3. Weld longitudinal bulkhead insert butts
4. Weld longitudinal bulkhead stiffener inserts.

Figure 12-10 illustrates the erection joint for decks and bulkheads and provides the welding sequence for attaching the stiffener inserts.



Assembly and Welding Sequence

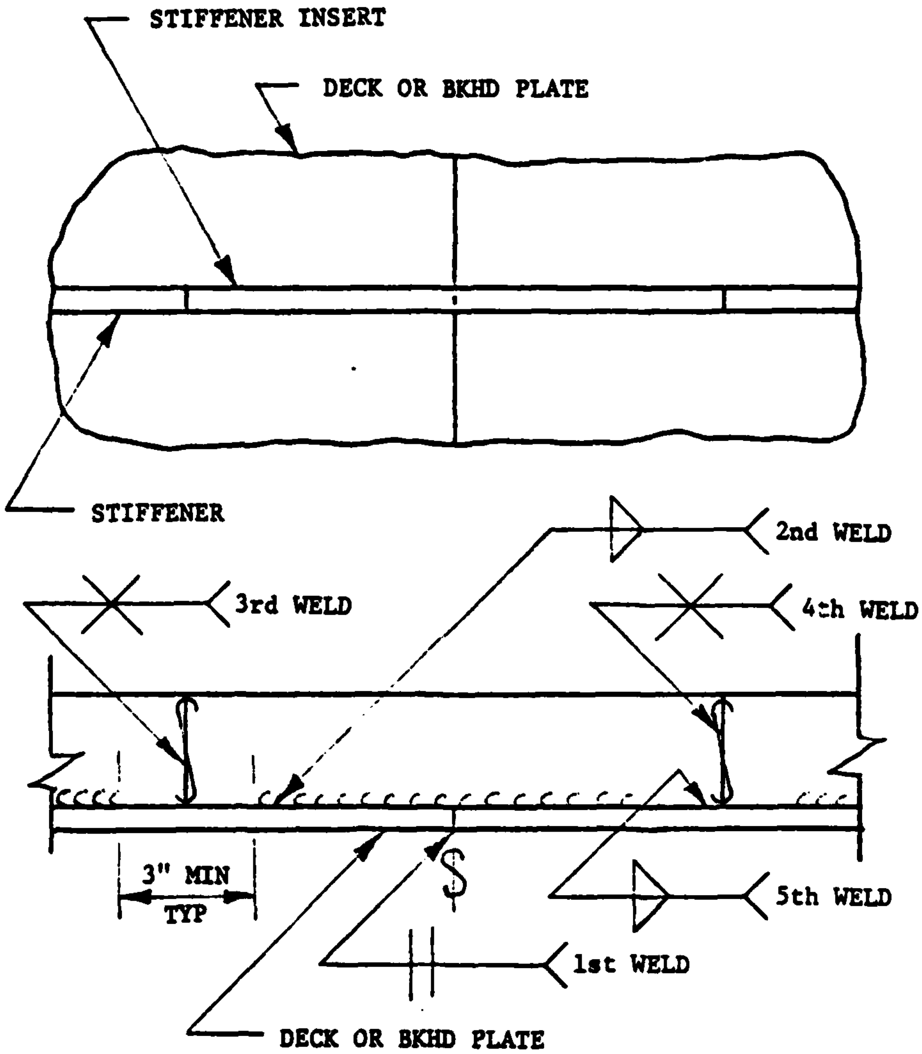
1. Erect and brace transverse bulkhead assembly into position.

2. Make vertical fillet welds as indicated or by use of back-step sequence.

3. Make deck intersection fillet weld starting at center of the stiffened side and progressing simultaneously toward both longitudinal bulkheads.

4. Make final deck intersection fillet weld progressing simultaneously from panel center toward both longitudinal bulkheads.

Figure 12-9. Assembly and Welding Sequence for Transverse Bulkhead Sections.



SEQUENCE OF WELDING

1. Weld deck or bulkhead butt joint. Grind weld smooth in way of crossing member.
2. Weld stiffener insert to deck, both sides.
3. Weld stiffener insert but joint on one end.
4. Weld stiffener insert butt joint on other end.
5. Weld remaining fillet joints, both sides.

Figure 12-10. Welding Sequence for Major Assembly Erection Joints.

12.3 DETAIL REQUIREMENTS

A detail may be described as the connection of at least two structural components which, when connected together, make up an assembly or subassembly. Standard details are those details which are used many times throughout the hull structure. Welding sequences for typical details e.g. intersections of plating butts and seams, miscellaneous joints, and inserts for piping penetrations are illustrated in Figure 12-11.

12.4 WELDING GUN CLEARANCE REQUIREMENTS

The geometric limitations necessary to provide adequate welding gun clearances for welding flat bar stiffeners and tee stiffeners to plating are illustrated in Figure 12-12.

12.5 ALIGNMENT AND FAIRNESS

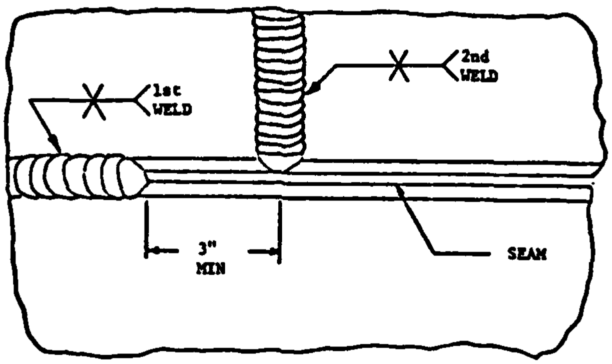
General requirements for alignment and fairness of the hull structure are specified herein. The requirements for internal structure and all external surfaces are contained in paragraphs 12.5.1 and 12.5.2 below.

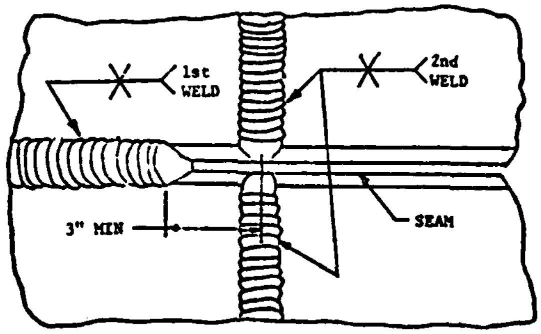
12.5.1 ALIGNMENT REQUIREMENTS

12.5.1.1 Plate Alignment Tolerances -- Where structures are clamped or tacked ready for welding, alignment of surfaces in way of butt joints will be such that, after welding, the maximum offset deviation from the nominal alignment specified on the drawings will not exceed 1/16 inch for plating less than 3/8 inch thickness or 1/8 inch for plating of 3/8 inch or greater thickness.

12.5.1.2 Structural Framing Alignment Tolerances -- Butt joints in structural framing including panel stiffeners will comply with the requirements of paragraph 12.5.1.1 above. Discontinuous

SEAM AND BUTT INTERSECTIONS IN PLATING





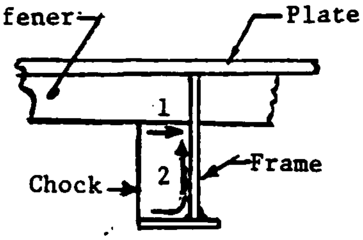
SEQUENCE OF WELDING:

1. Weld seam on one side of butt stopping at least 3 inches from butt.
2. Weld butt.
3. Dress end(s) of butt weld against seam to match seam joint preparation requirements.
4. Complete seam weld.

Figure 12-11. Welding Sequences for Typical Structural Details (Sheet 1 of 5)

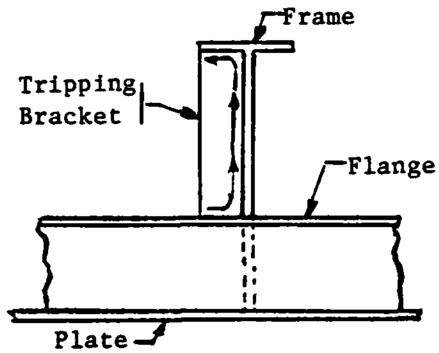
Sequence

1. Fit and clamp chock in position; use no tack welds.
2. Make chock to stiffener butt weld.
3. Make chock to frame fillet welds.



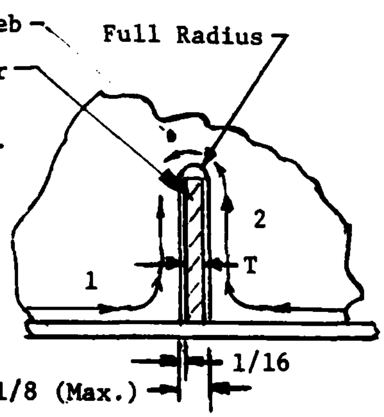
Chock to Flatbar Stiffened Plate

1. Fit and clamp bracket in position.
2. Make fillet welds as shown.



Tripping Bracket to Tee Stiffened Plate

1. Fit and clamp crossing member in place.
2. Make fillet welds in sequence indicated. Start welds midway between stiffeners.

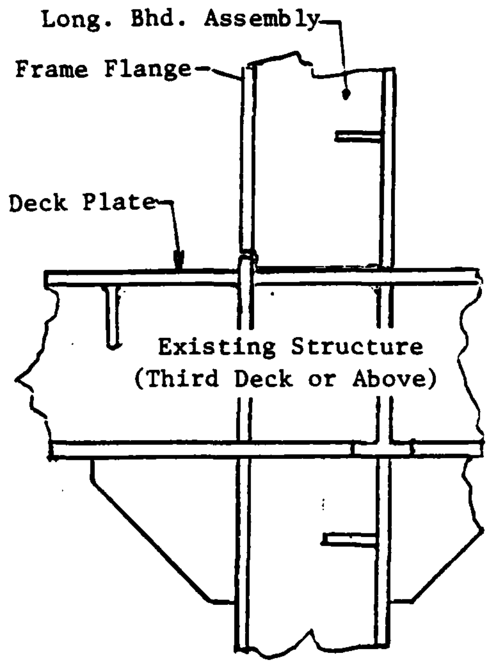


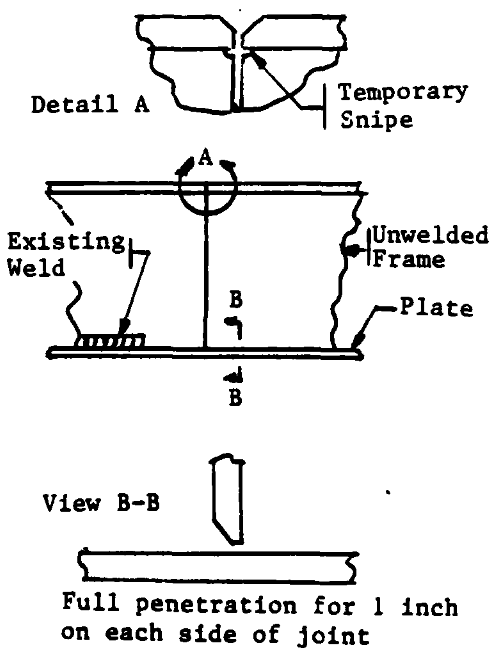
Frame Web to Flatbar Stiffened Panel

Figure 12-11. Welding Sequence for Typical Structural Details (Sheet 2 of 5)

Assembly and Weld Sequence

1. Trim and fit frame end to interface flatbar and deck and position for welding.
2. Make butt weld between frame flange and interface flatbar.
3. Fillet weld frame side of bulkhead plate to deck plate progressing from mid frame towards frame web.
4. Fillet weld frame web to deck.
5. Fillet weld opposite side of bulkhead plate to deck plate.

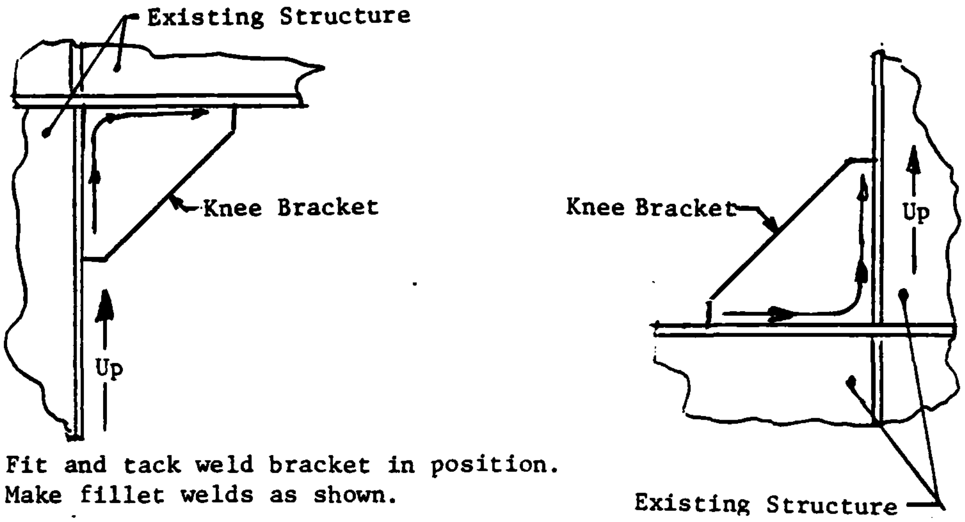




Assembly and Weld Sequence

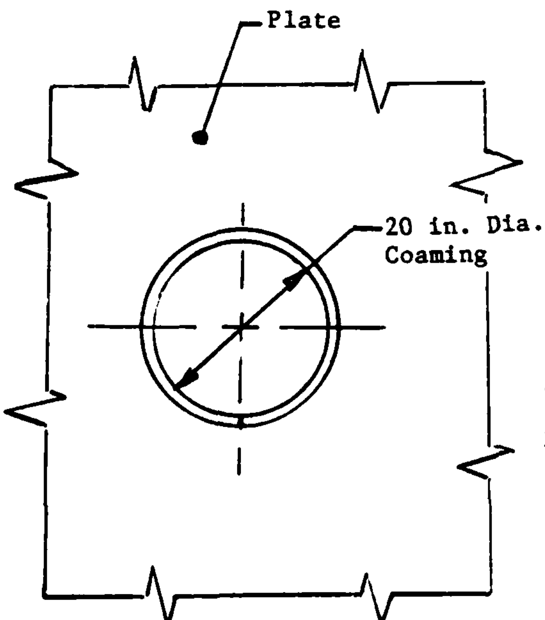
1. Make joint preparations as indicated and clamp unwelded frame in position.
2. Make butt joint between frame flanges.
3. Make transition weld from fillet to full penetration tee joint and progress along frame web butt joint.
4. Grind out weld material at the intersection of web butt joint and plate.
5. Make final weld across the full penetration transition.

Figure 12-11. Welding Sequence for Typical Structural Details (Sheet 3 of 5)



1. Fit and tack weld bracket in position.
2. Make fillet welds as shown.

Knee Bracket Weld Sequence

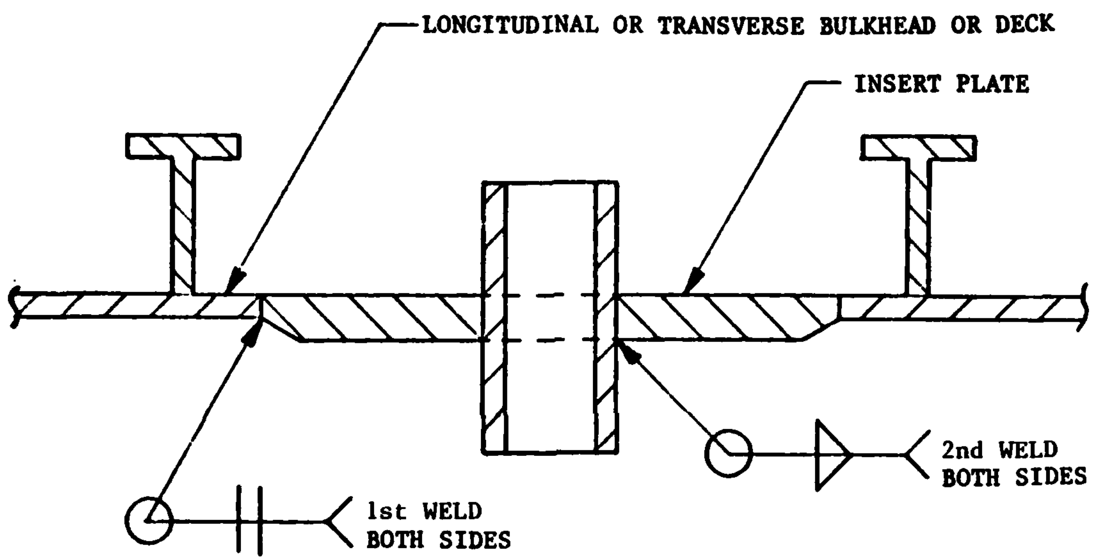


1. Make butt welds in coaming.
2. Fit and tack coaming in position.
3. Fillet weld coaming to plate.

Weld Sequence for Coaming in Access Opening

Figure 12-11. Welding Sequence for Typical Structural Details (Sheet 4 of 5)

PIPING PENETRATION INSERT DETAIL



SEQUENCE OF WELDING:

1. Weld insert plate to cut member, both sides.
2. Weld pipe sleeve to insert plate, both sides.

NOTE: Penetrations are considered secondary connections and will be sequenced upon completion of all other structural welds within the immediate area.

Figure 12-11. Welding Sequences for Typical Structural Details (Sheet 5 of 5).

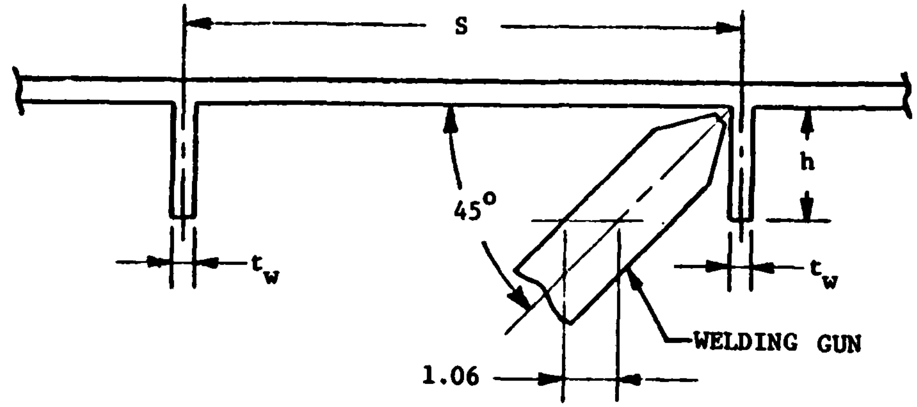
Limitations on Geometry:

$h_{max} = S - 1.06 - t_w$

For 10" stiffener spacing,

$h_{max} = 8.94 - t_w$

NOTE: Gun Dia. = 1.5"



a) FOR FLAT-BAR STIFFENERS

Limitations on Stiffener Proportions:

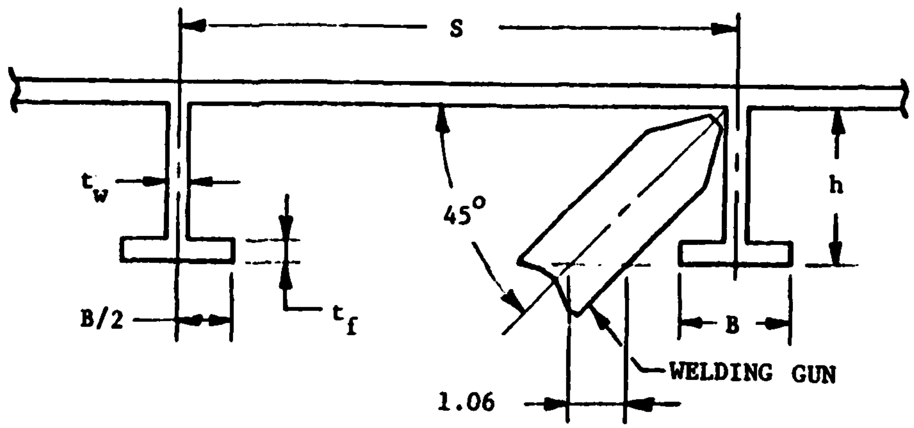
$h_{min} = \frac{B+t}{2} + 1.06$

Also, for 10" stiffener spacing:

$B_{max} = 7.88 + t$

NOTE: Gun Dia. = 1.5"

$t_w = t_f = t$



b) FOR TEE STIFFENERS

Figure 12-12. Gun Clearance Requirements for Fillet Welding.

members of structural framing on opposite sides of a through member will line up back-to-back with a limit of error in offset not exceeding one half of the thickness of the through member. Where the discontinuous member is a structural shape, both webs and flanges will be aligned within this limit.

12.5.1.3 Flatbar Stiffener Straightness Requirements -- The maximum deviation in the plane of flatbar stiffeners between each frame will be 3/16 inch as illustrated in Figure 12-13. Deviations in excess of those above will require straightening or the installation of stabilizing chocks or equivalent.

12.5.1.4 Flarbar Stiffener Offset Tolerances -- The allowable offset resulting from lateral misalignment of the stiffeners between mating assemblies will be determined from the stiffener height and thickness and the length of the stiffener insert as illustrated in Figure 12-14.

12.5.1.5 Alignment Aids -- The alignment of the members to be joined may be assisted by the use of welded erection clips, strong-backing clamps, or fitting attachments similar to those illustrated in Figure 12-15. Temporary welded attachments will be kept to a minimum due to the effects of the heat affected zone and the resultant distortion in the area of the attachment weld.

12.5.1.6 Removal of Temporary Attachments -- Removal of temporary welded attachments such as lugs, clips or strongbacks will be done using methods which minimize the extent of fabrication scars. Hammers or sledges are not to be used. All ground off attachments will be inspected to the same requirements and standards as the adjacent welds.

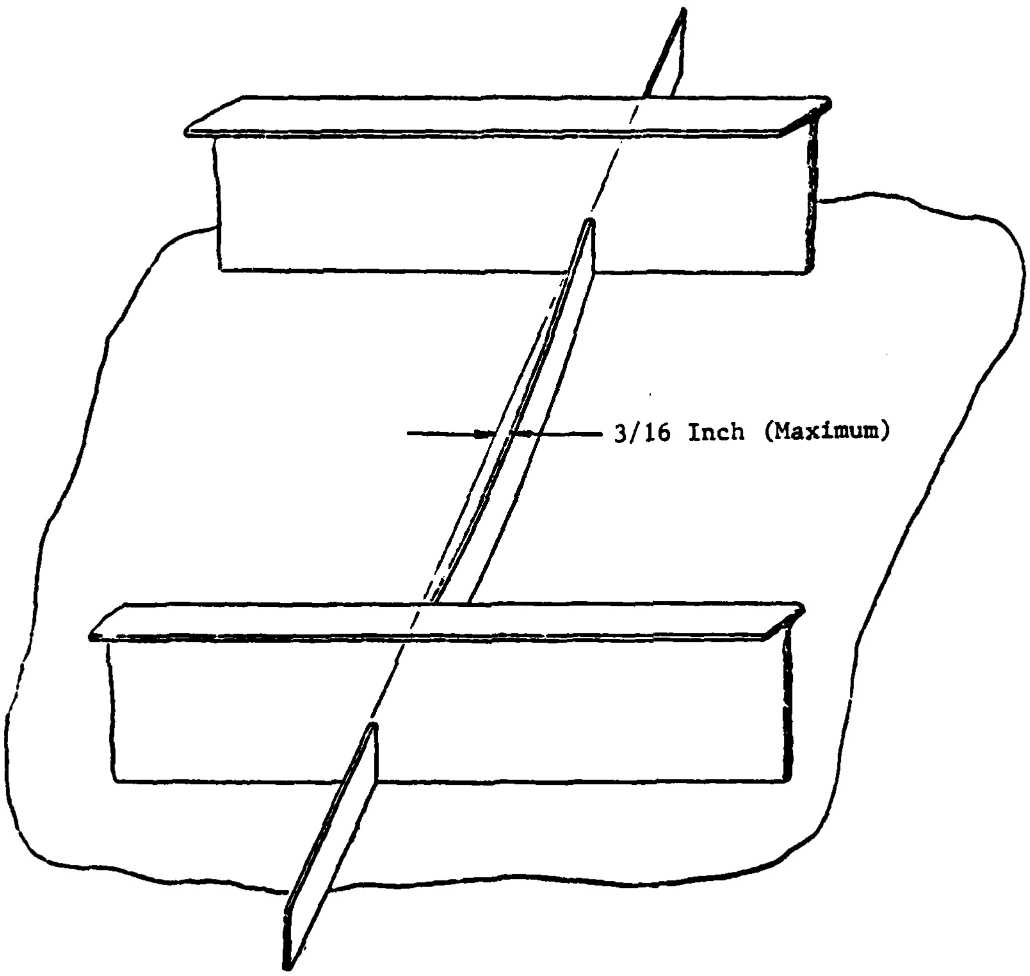


Figure 12-13. Flatbar Stiffener Straightness Requirement.

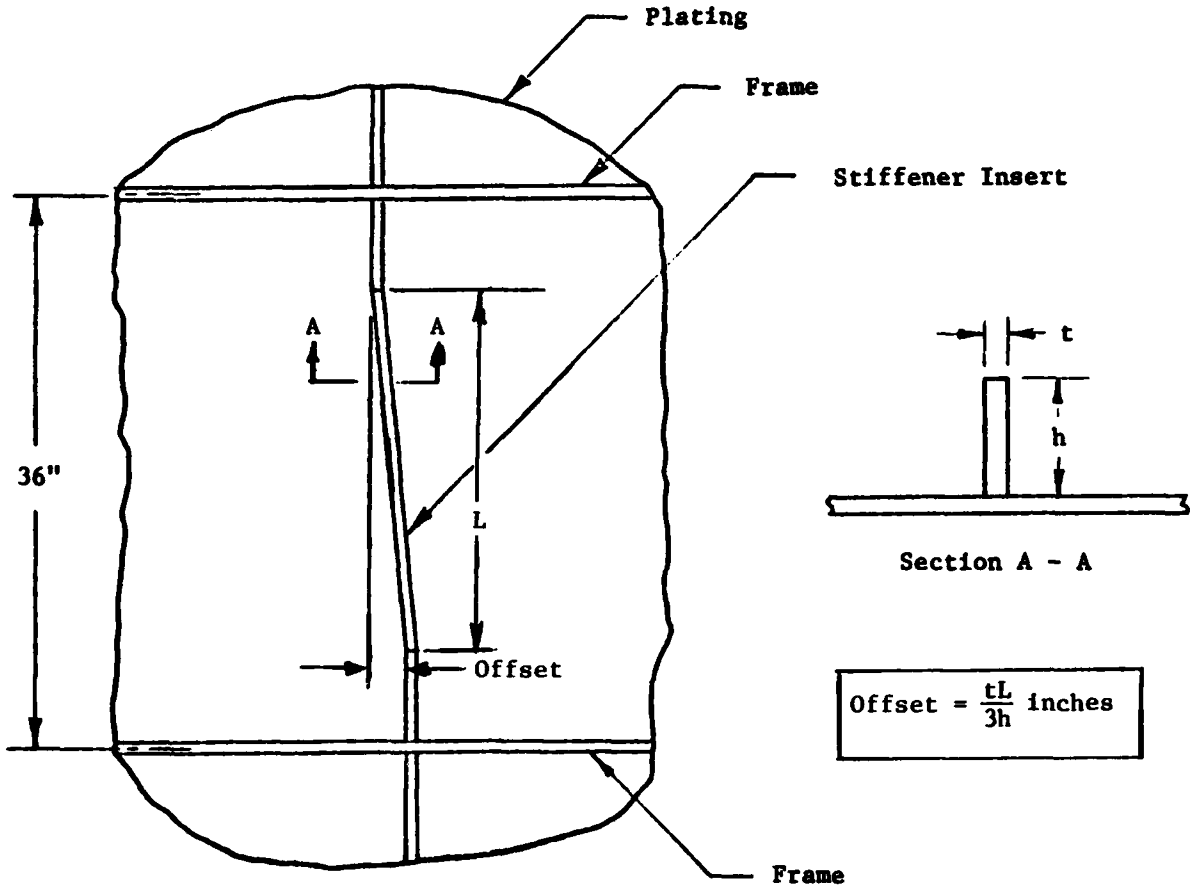


Figure 12-14. Maximum Permissible Offset Misalignment of Flatbar Stiffeners.

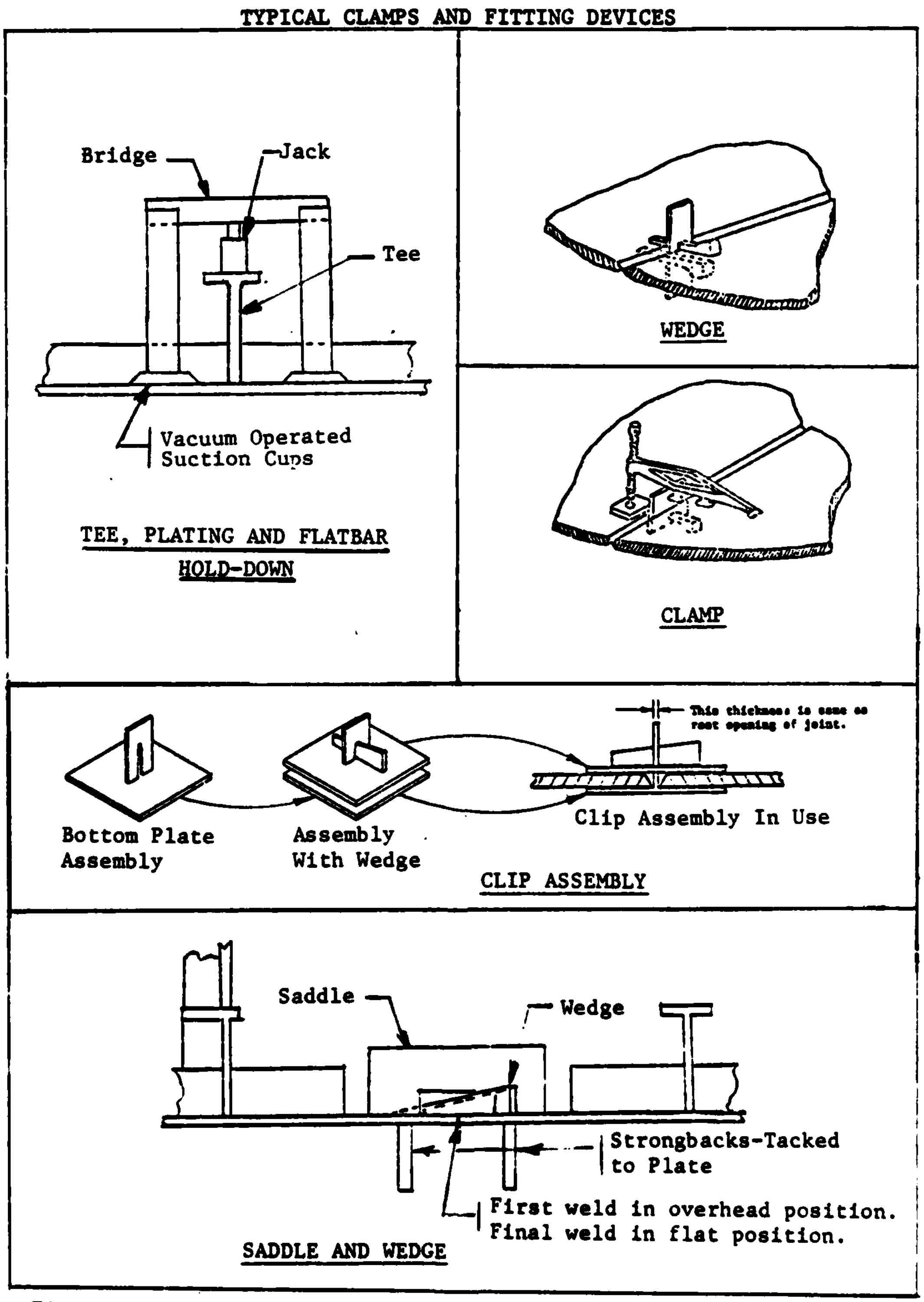
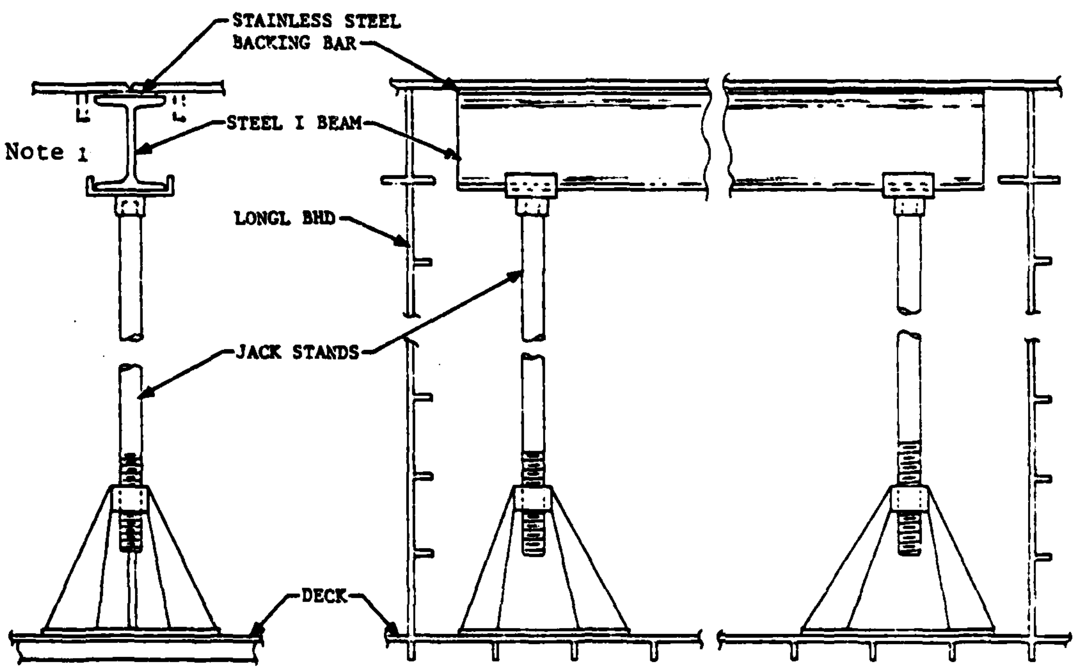


Figure 12-15. Typical Plate Alignment Aids (Sheet 1 of 3).

BACKING SUPPORT FOR ONE SIDE ERECTION BUTT JOINTS



NOTES: 1. Plate alignment is achieved by pre-set strongbacks or by use of saddle and wedge.

2. Hydraulic jacks may be used instead of screw jacks.

Figure 12-15. Typical Plate Alignment Aids (Sheet 2 of 3).

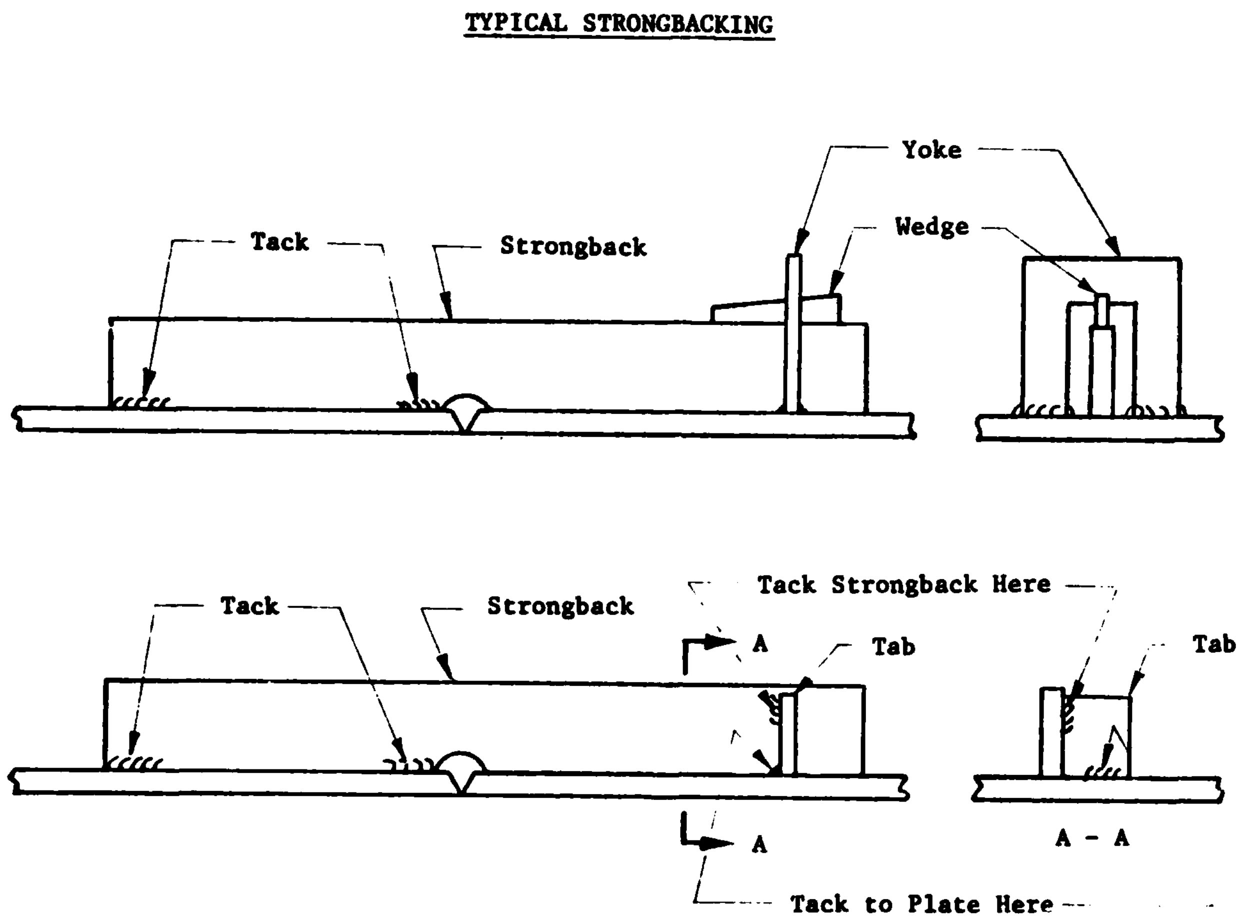


Figure 12-15. Typical Plate Alignment Aids (Sheet 3 of 3).

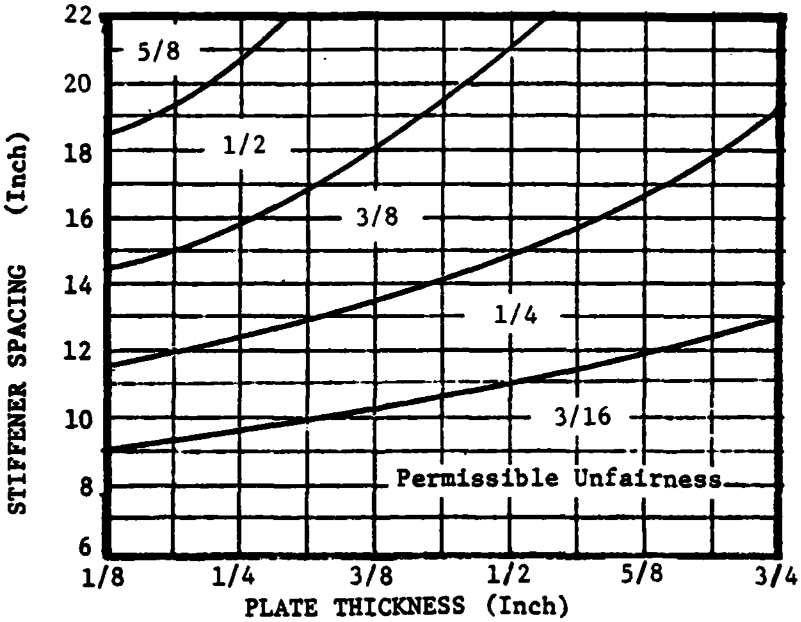
12.5.2 STRUCTURAL FAIRNESS

12.5.2.1 Plate Unfairness -- Unfairness of all welded plating, will not exceed the applicable tolerances shown in Figure 12-16. Permissible unfairness will result in a generally fair curve across the panel, except that an additional deviation of 1/8 inch from the fair curve is permitted in way of welded butts and seams in all areas other than those defined below in paragraph 12.5.2.2. Sharp knuckles or joggles in way of stiffeners will be minimized by use of fabrication techniques such as clamping or strongbacking which will minimize distortion.

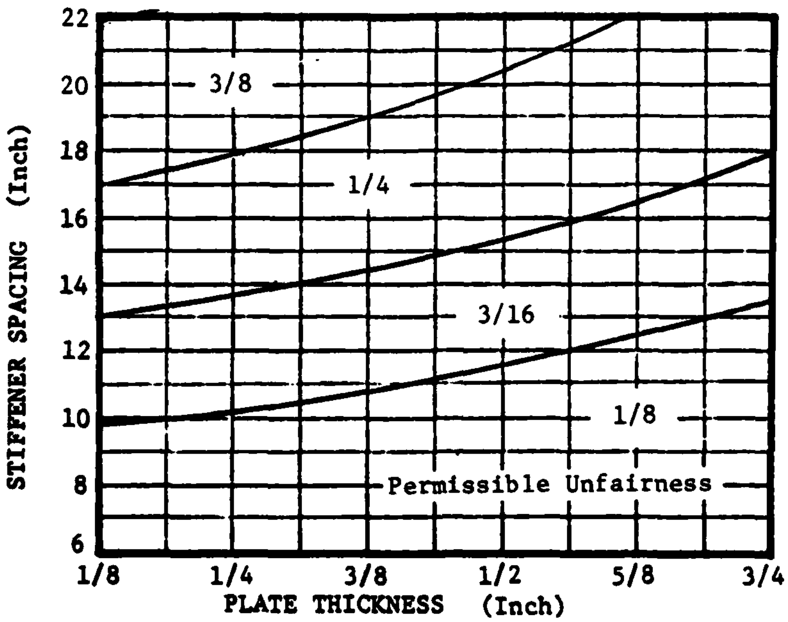
12.5.2.2 Fairness Requirements for Critical External Hull Surfaces -- The sidehull exterior outboard surfaces below the spray rail and its projection aft to the transom, the sidehull inboard exterior surfaces below the 6 foot waterline, and the seal wiping areas on the sidehull inboard surfaces are defined as critical and will comply with the fairness requirements shown in Figure 12-16B. Permissible unfairness will result in a generally fair curve across the panel, and the deviation in way of transverse and/or vertical butt joints will not exceed that permitted by the smoothness requirements of Paragraph 14.4.3.

12.5.2.3 Unit Assembly and Unit Assembly Interface Tolerances -- Design dimensions will be derived from Hull Lines Drawing TL802009 for the hull structure, drawing TL159001 for the superstructure, and production drawings for locations of mold lines within the ship structure. Allowable tolerances will be as specified in Paragraph 3.3.4.1 of the 3KSES Hull Structure Specification T23100001.

To assure deck and bulkhead interface compatibility, the actual dimensions of each completed assembly unit will be considered during subsequent fabrication of interfacing units. The washout between the mold line planes of matching decks and bulkheads at erection interfaces will not exceed 3/8 inch, and the alignment of interconnecting members will be in accordance with Paragraphs 12.5.1.1, 12.5.1.2 and 12.5.1.4. above.



A. Requirements for Internal Decks, Wet Deck, Bulkheads and Superstructure.



B. Requirements for Hull Shell and Weather Decks.

Figure 12-16. Permissible Unfairness in Hull Structure Plating.

The total deviation from the design height from the Wet Deck to the 01 Level shall not exceed 3/4 inch and from the Wet Deck to the Main Deck shall not exceed 5/8 inch.

Measurements will be taken during assembly fabrication, at final fit-up in the marine assembly facility, and after welding to the next assembly. All dimensions that exceed the allowable tolerance(s) will be considered nonconforming to requirements and submitted to the Material Review Board for disposition as approved by the Government Representative.

12.5.2.4 Ship Tolerances -- Ship tolerances will be as specified in Paragraph 3.3.4.2 of the 3KSES Hull Structure Specification T23100001. Measurements will be made as specified in Paragraph 12.5.2.5 below and the results will be reported to the Government Representative.

12.5.2.5 **Measurement Reference Temperature -- The various tolerances specified above in paragraphs 12.5.2.2, 12.5.2.3 and 12.5.2.4 are based on a structure temperature of 70°F. Measurements to determine compliance with the specified requirements will be made at a time when the temperature throughout the structure is stable and constant. The resulting actual measurements will be adjusted to the reference temperature, if required, as follows.**

$$L_A = \frac{L_O}{1+.0000133(T_{observed} - 70)}$$

$$\text{Deviation} = L_A - L^*$$

Where L_A = the observed dimension corrected to 70°F, in inches

L_O = the observed dimension in inches

T_O = The temperature in °F when the observed dimension was obtained.

L* = Required dimension per drawing, inches.

12.6 STRAIGHTENING ALUMINUM

12.6.1 GENERAL REQUIREMENTS -- Where preventive measures are insufficient to control distortion, and fairness tolerances are exceeded, straightening will be employed to the minimum extent necessary to bring the plating within the tolerances specified herein.

Flame straightening techniqueswill be permissible only when designated by the Material Review Board for a specific application. When used, flame straightening will be performed in accordance with written procedures approved by NAVSEA.

12.6.2 STRAIGHTENING METHODS

12.6.2.1 Structural Members -- Structural members may be straightened by mechanical means such as hydraulic jacking or use of a mechanical press in combination with a fixture of sufficient rigidity to restrain the member to be straightened.

12.6.2.2 Sub-Assemblies -- Plate buckling may be minimized by slitting the plate in highly distorted areas and rewelding or welding on the plate surface in accordance with Paragraph 13.13 of this document.

13 / WELDING REQUIREMENTS

13.1 SCOPE

This section contains welding requirements for the 3KSES hull structure. Improvements in welding techniques gained from experience with on-going weld development and structure fabrication efforts are reflected in these requirements.

13.2 WELDING PROCEDURE AND PERFORMANCE QUALIFICATIONS

Welding procedures, welders and welding operators will be qualified in accordance with the requirements of Section 4 of this document prior to their employment on production work.

13.3 WELD JOINT AND SURFACE PREPARATION

Plate edges or surfaces will be prepared for welding in accordance with the requirements of Section 14 of this document.

13.4 WELD JOINT CONFIGURATION -- Weld joint configuration prior to welding will be in accordance with the requirements of Section 11 of this document, or as otherwise allowed by qualified weld procedures.

13.5 WELDING MATERIALS

Welding materials will comply with the requirements specified in Section 10 of this document.

13.6 PREHEAT PROCEDURE AND CONTROL

13.6.1 METHODS -- Preheat may be applied to the weld joint prior to welding by any of the following methods and in any combination:

a. Resistance heaters

b. Induction

c. Radiation (heat lamps)

Open flame torches will be prohibited unless prior approval of NAVSEA is obtained.

13.6.2 APPLICATION -- Preheat, when used, will be of the soaking type and uniformly distributed adjacent to the joint to be welded. Heating will be such as to insure that the entire length to be welded is up to the required preheat temperature prior to welding. When the ambient temperature is below 60^{o} and/or there is evidence of moisture on the material surface, preheat will be applied until the area is warm to the touch and dry.

13.7 PREHEAT AND INTERPASS TEMPERATURES

13.7.1 GENERAL REQUIREMENTS -- Preheat and interpass temperatures will be restricted to a maximum of $150^{o}F$ or as otherwise established by an approved procedure qualification test. Minimum material temperature prior to welding will be $60^{o}F$.

13.7.2 PREHEAT AND INTERPASS TEMPERATURE MEASUREMENT -- Temperatures of $115^{o}F$ and above will be measured using temperature indicating crayons or other appropriate means. For checking the required minimum preheat

temperature, the material temperature will be considered the same as the ambient temperature in the general weld area if the temperature of the material has essentially stabilized. Preheat temperature will be measured on the surface of the material on the side from which welding will be performed and within 3 inches of the area to be welded, but not within the weld joint. Interpass temperature will be measured on the surface of the material on the side from which welding will be performed and within 1 inch of the weld joint edge adjacent to the area of the start of the next weld pass. When welding thicker members to thinner members, care must be exercised to insure the thicker member has reached the uniform preheat temperature without overheating the thinner member.

13.8 POST WELD HEAT TREATMENT

Welded aluminum hull structural assemblies will not be post weld heat treated for the purpose of reducing residual stresses unless prior NAVSEA approval is obtained.

13.9 WELDING EQUIPMENT

Constant current type power supplies will be employed where the GTAW process is used and either constant voltage or constant current type equipment employed where the GMAW process is used. Each welding system will include calibrated volt meters and ammeters. All portable welding systems will be equipped with primary voltage manual cut-off systems.

Each welding machine will be equipped with an automatic purge device which allows shield gas to flow a preset time to insure that the gas is free of moisture prior to arc ignition. Reinforced tygon or equivalent plastic hoses will be employed for the inert gas flow systems. Rubber hoses will only be used in watercooling systems. When a welding procedure requires the use of a gas mix to produce weld, an approved gas mixing device or premixed bottle gas will be used.

All welding equipment will be properly maintained by the responsible welding operator on a daily basis to insure safe and efficient operation. Welding

machines used for production will meet OSHA safety requirements with periodic maintenace checkout to verify compliance.

An automatic welding system will be utilized for 3KSES panel element fabrication as illustrated in Figure 13-1. This system will consist of two vacuum chuck welding tables and a beam gantry. The vacuum chuck table will support and clamp the plate to a single location during all welding operations. The gantry beam will support a carriage which will contain provisions for attachment of welding heads and positioners to locate and clamp stiffeners in position for fillet welding to the plate. The carriage will have three axis motion and will be operated from a control station located in one leg of the gantry.

13.10 SPECIAL FABRICATION FIXTURES AND ASSEMBLY TECHNIQUES

Any fixtures or other devices required for use in the fabrication of welded hull assemblies will be constructed such that welding operations may be performed without hazard to the operator and that the required dimensional tolerances of the assembly can be maintained from start to finish.

13.11 REPAIRS

13.11.1 GENERAL -- For the purpose of this document, every required repair will be classified into one of the following categories:

a. Repairs to Material Surfaces

b. Repairs to Weld Surfaces

c. Repairs of Internal Flaws in Welds

13.11.2 REPAIRS TO MATERIAL SURFACES -- Repair welding for scars and other fabrication damage will be limited to those locations which cannot be corrected by grinding to the extent specified in Section 14 of this document. When any condition exists that cannot be corrected by

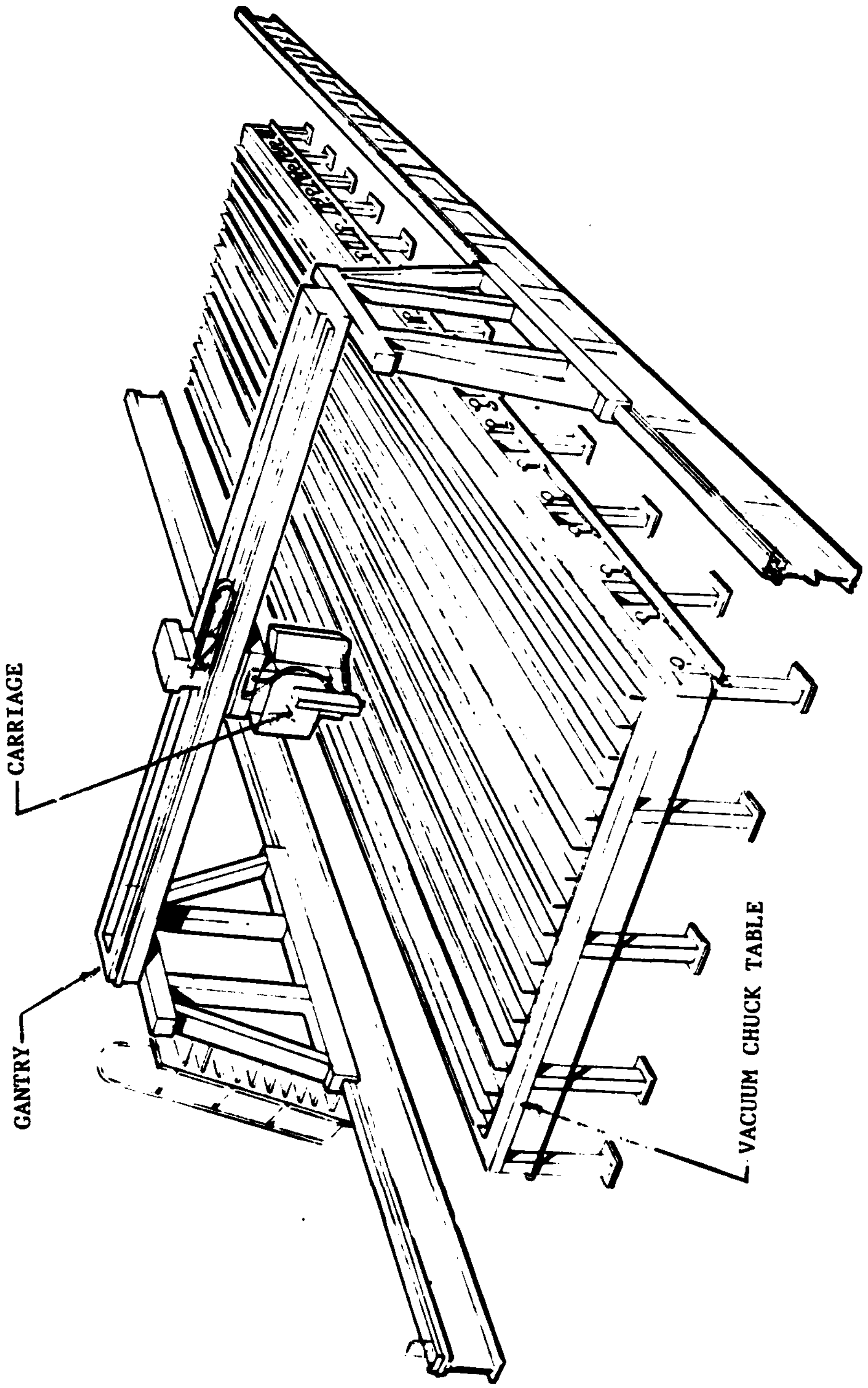


Figure 13-1. Automatic Panel Welding System.

buttering or build-up as permitted in this document, e.g. excessive root opening, a replacement part or insert will be installed to correct the condition. All such repair welds will be made using qualified procedures and will be subject to the inspection requirements of Section 6 of this document.

13.11.3 REPAIRS TO WELDS -- Welding to correct underfill and undercut weld edges will be limited to those areas which are deeper than the allowances specified in Section 8 of this document. Internal weld flaws will be repaired, where necessary and authorized, to meet the acceptance standards of Section 8 of this document. Where repairs are authorized, defective areas will be removed to sound metal and contoured so as to allow deposition of weld metal using approved weld repair procedures. The weld repairs will be inspected in accordance with the requirements of Section 6 of this document, and the weld repair quality will meet the applicable requirements of the original weld.

13.12 TACK WELDS

Tack welds will be made with the same type electrode as that to be used in the final weld, will be of suitable quality, and will be deposited so as to facilitate incorporation in the final weld. Cracked tack welds and those of poor quality or workmanship will be removed and, if required, replaced.

13.13 STUD WELDING

Stud welding procedures and welding operators will be qualified in accordance with Section 4 of this document prior to their employment on production work. The base metal surface will be prepared as specified and inspection will be performed in accordance with paragraph 6.9 of this document.

13.14 RESIDUAL STRESS AND DISTORTION

Distortion of structural hull assemblies and the associated residual stress will be removed by either mechanical means or deformation or by localized slitting and welding of plate where the greatest amount of stress and/or distortion is located. Weld bead(s) deposited on the plating surface (i.e. shrink welds) in the areas where distortions are present may be substituted for plate slitting where slitting is determined impractical. The number of slits, or shrink welds, will not exceed two in any ten inch span of plate. Welded slits or shrink welds will be treated as butt welds for inspection purposes and will conform to the applicable butt weld acceptance requirements.

14 / WORKMANSHIP REQUIREMENTS

14.1 SCOPE

This section contains the minimum requirements for workmanship practices and methods to ensure sound welded joints in aluminum hull construction.

14.2 EDGE PREPARATION

14.2.1 MATERIAL REQUIREMENTS -- Material issued from storage will be inspected to assure adequate quality. Material surfaces will be free of exfoliation and other corrosion except light watermarks. Surfaces will also be free of objectionable scratches, nicks, gouges and other irregularities. Where metal removal is required to provide acceptable surface conditions, the plate thickness will not be reduced more than 10% of the plate nominal thickness or 1/16 inch, whichever is less.

14.2.2 EDGE TRIM AND WELD JOINT PREPARATION -- Plate edge trimming including preparation for welding will be accomplished by any one or combination of the following methods:

a. Machining
b. Grinding
c. Plasma arc cutting
d. Sawing
e. Shearing

Sheared edges of plates and details will be trimmed back, by means other than shearing, a distance equal to at least one-half the material thickness prior to welding.

14.2.3 EXPOSED EDGES -- Exposed sheared edges, when subject to the external hull environment or located below the off-cushion waterline inside the hull, will be clad welded for corrosion resistance.

14.2.4 WELD JOINT SURFACE PREPARATION -- Surfaces to be welded upon and adjacent surfaces for a distance of at least 1/2 inch from the expected weld area will be mechanically or chemically cleaned to remove oil, grease, markings, moisture, and oxide. Immediately before welding the reformed oxide film will be removed from the joint faying surfaces and at least 1/4 inch beyond the edge of the weld fusion zone using the cleaning method specified in the written weld procedure. Wire brushes used for cleaning will be made from stainless steel wire. Where joint surfaces from which the oxide has been initially removed are inaccessible after fit-up, oxide removal immediately prior to welding will only be accomplished on the accessible joint surfaces.

14.2.5 WELD ROOT PREPARATION -- In full penetration joints to be welded from both sides, the root of the welding done on the first side will be chipped, ground, or gouged before any welding is started on the opposite side. The weld root area will be cleaned to sound metal and contoured so as to allow deposition of a sound pass from the second side. Immediately before welding, the reformed oxide film will be removed as specified above in paragraph 14.2.4.

14.3 WELD CONTOUR

14.3.1 GENERAL -- Contours of weld reinforcements will be free of sharp depressions or irregularities between adjacent or continuing passes and shall intersect the base material at the weld edges without undercut or overlap in excess of the requirements specified in Section 8 of this document. Mechanical means such as grinding or shaving will be premitted to reduce the reinforcement surface irregularity to an acceptable contour. When welding is required to correct improper contouring, it will be performed in conformance with the requirements of Section 13 of this document.

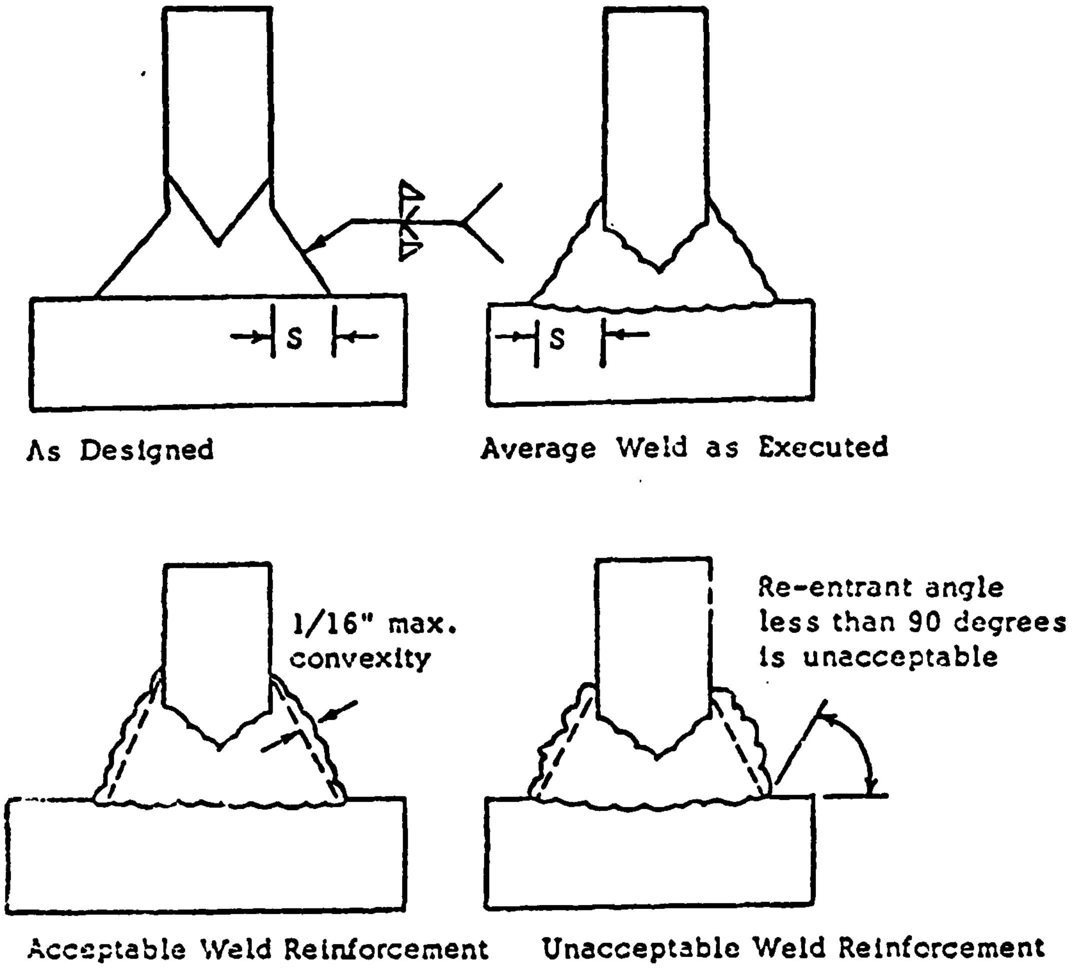
14.3.2 WELD EDGES -- Weld edges which exhibit undercut in excess of the acceptance standards in Section 8 of this document will be repaired by welding or grinding in accordance with the requirements specified below in paragraph 14.4.4. Weld bead overlap and excessive roughness will be corrected by mechanical means.

14.3.3 WELD CRATERS -- All weld craters will be free of visible cracks. Avoidance of crater cracks may be accomplished by the use of temporary run-off tabs or by the welder momentarily reversing the direction of welding travel just prior to breaking the welding arc and subsequently removing the extra reinforcement containing the crater.

14.3.4 BUTT WELD REINFORCEMENT -- Butt weld reinforcements will be in accordance with the requirements of Section 8 of this document.

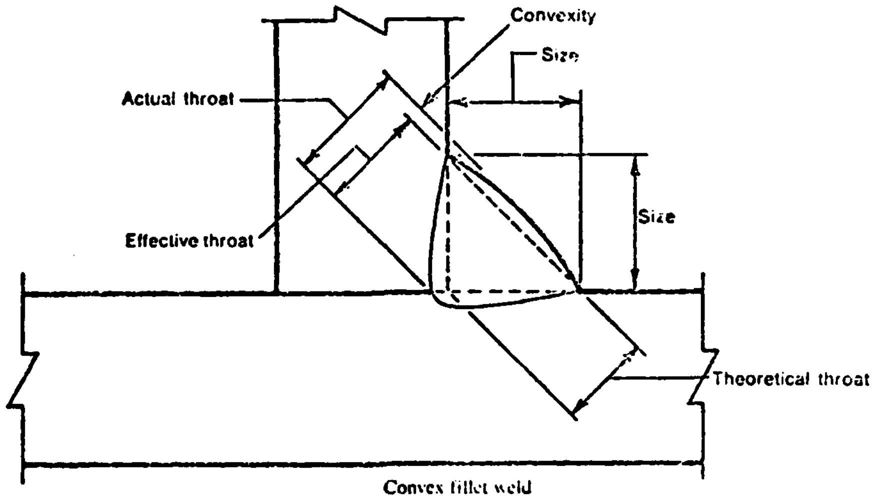
14.3.5 FULL AND PARTIAL PENETRATION TEE JOINT REINFORCEMENT -- Fillet reinforcements on full and partial penetration tee joints will be at least equal to the size specified in Section 11 of this document or on the applicable drawings and will have a reinforcement contour meeting the requirements shown Figure 14-1. Fillet reinforcement sizes in excess of those required by the applicable drawings are acceptable providing the contour requirements of Figure 14-1 are met.

14.3.6 FILLET WELD REQUIREMENTS -- When the opening between elements of a fillet-welded joint exceeds 1/16 inch as a nominal condition along the joint, the fillet size will be increased by an amount equal to the excess of the opening above 1/16 inch. Fillet welds will be wrapped around the ends of members to form a continuous path of reinforcement. Fillet weld contours will be in accordance with the requirements of Figure 14-2.

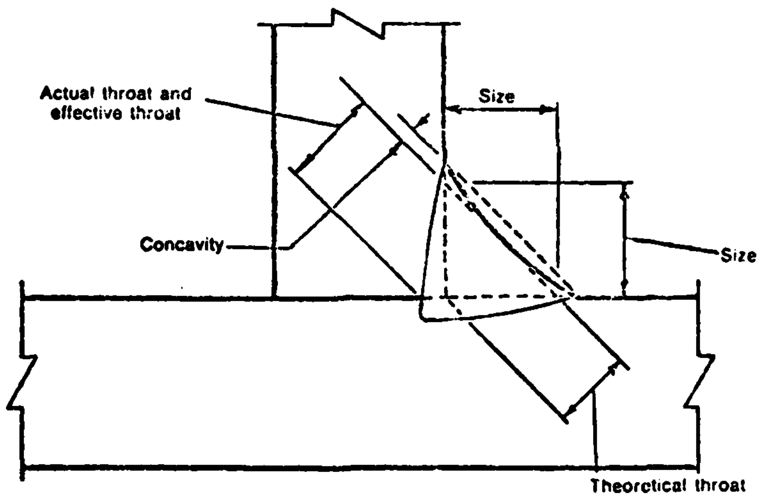


NOTE: S = Required reinforcement fillet size.

Figure 14-1. Reinforcement Contour Requirements for Full and Partial Penetration Tee Joints.



Convex fillet weld



Concave fillet weld

NOTES:

1. Fillet weld convexity will not exceed 1/16 inch.
2. Re-entrant angle less than 90 degrees will not be acceptable.
3. Fillet size in excess of that required by the drawing will be acceptable provided that the contour is in accordance with the above notes.

Figure 14-2. Fillet Weld Reinforcement Contour Requirements.

14.4 WELD SURFACES

14.4.1 MATERIAL SURFACE CORRECTION -- When employed for the correction of material surface defects, grinding will produce a smooth depression blended into the surrounding surface. Where nicks, gouges, etc. exceed the depth limitations specified for weld undercut in Section 8, repairs will be accomplished as specified in 14.4.4 below.

14.4.2 SURFACE PREPARATION FOR NONDESTRUCTIVE TESTING -- Prior to all nondestructive testing except visual (VT), the contour of the weld, except for allowable undercut, will be smoothed, if required, only to the degree necessary that the surface irregularities will not mask discontinuities within the weld metal. Excessive weld ripples or weld surface irregularities will be removed by any suitable mechanical process.

14.4.3 BUTT WELDS IN OUTER HULL SURFACE -- Where removal of the exposed butt weld reinforcements is required as specified in paragraph 8.4.1.13 of this document, the reinforcement will be machined, ground and/or sanded flush or to blend into the adjacent plating surfaces. The contour will be smooth with no visible steps or discontinuities, and no slope on the finished contour will be steeper than 1 in 10 referenced to the adjacent plating.

14.4.4 UNDERCUT AND OTHER WELD-EDGE CORRECTIONS -- Undercut and other weld-edge defects will be repaired by grinding and/or welding as follows:

14.4.4.1 Grinding -- Grinding will be permitted to correct weld edge conditions which do not meet the acceptance standards of Section 8 of this document, provided such grinding does not reduce the thinner adjacent plate thickness the lesser of 1/16 inch or 10 percent of the nominal plate thickness. The depth of grinding will be measured from the unground surface adjacent to the ground area.

14.4.4.2 Weld Repair -- The repair of undercut and other weld-edge defects (including ground areas exceeding the above defined depth limitations) by welding will be accomplished by depositing a bead in the undercut area which will fair into the existing weld. Such repairs will be authorized in accordance with the contractor's Quality Assurance Procedures and will be made using weld repair procedures which have been qualified as specified in Section 4 of this document.

14.5 TEMPORARY SNIPES

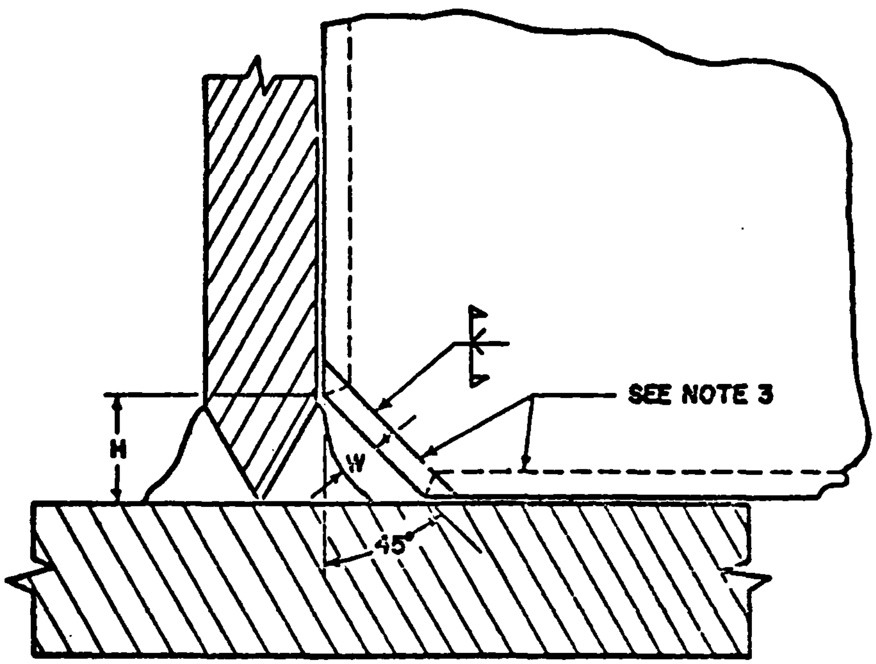
Where continuous welds in systems of intersecting structure are required, temporary snipes will be provided to assure the deposition of sound metal at such intersections. Temporary snipe locations will be governed by details of the welding sequence. Snipe dimensions will be of adequate size to allow satisfactory completion of welding in the through joint and will be kept as small as possible to facilitate welding of the snipe closure. Two examples of temporary snipes are shown in Figures 14-3 and 14-4.

14.6 BUTTERING OR BUILDUP

Buttering or buildup by welding on the joint surfaces to correct over-size root opening or errors in joint preparation will be accomplished prior to fitting. Qualified weld procedures will be used and the buildup will not exceed the lesser of 1/2 the plate thickness or 3/16 inch on each joint edge. When root openings cannot be corrected within this limitation, repair will be performed in accordance with the requirements in Section 13 of this document.

14.7 REMOVAL OF WELDED ATTACHMENTS AND SHRINKAGE WELD REINFORCEMENTS

In the removal of welded attachments and exposed shrinkage welds, the weld reinforcements will be removed by shaving, chipping, gouging,



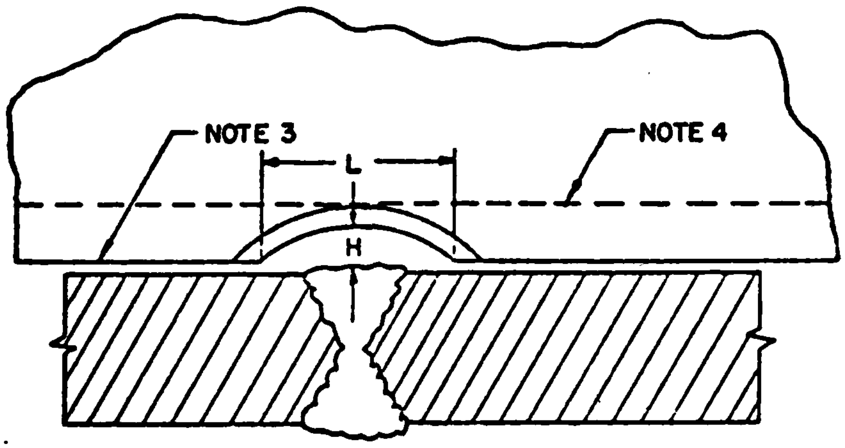
Notes: (1) Height of the snipe (H) will be such that the corners of the snipe clear the intersecting weld preparation as shown above.

(2) Width of the snipe opening (W) will be 3/16" min. - 5/16" max.

(3) Regardless of whether design of the sniped member specifies bevelled or square edge preparation, the snipe will be bevelled as shown to insure maximum accessibility for welding.

(4) The snipe will be closed during welding of the periphery of the members in which they occur.

Figure 14-3. Typical Temporary Snipe in Corner of Connecting Structural Member Which Intersects Two or More Other Members



Notes:
(1) Length of snipe opening (L) to be 1/2" longer than width of butt weld, or backing bar (when used), which it crosses.
(2) Height of snipe opening (H) to be 3/16" min., 3/4" max.
(3) When design of the crossing member calls for square edge joint preparation, the edges of the snipe will be bevelled on each side to provide maximum accessibility to the butt.
(4) When design of the crossing member calls for single or double bevel edge preparation, the edges of the snipe will be bevelled to "fair-in" with the plate edge preparation bevel.
(5) All snipes are to be closed during welding of the joints in which they occur.

Figure 14-4. Typical Temporary Snipe in Structural Member Connection Crossing a Butt Weld

and/or grinding. Surface defects will be faired out by grinding, provided the depth limitations specified above in paragraph 14.4.4.1 are not exceeded. Where the depth limitations are exceeded, the defective areas will be repaired as specified in paragraph 14.4.4.2 of this document.

14.8 PEENING

Air blast shot peening of structural welds will be prohibited. However, brush peening or rotary flapper peening of welds will be permissible when designated by Engineering or the Material Review Board for each application. Detail peening requirements, techniques, controls and inspection/acceptance criteria will be defined for each application where the use of brush/rotary flapper peening is justifiable.

14.9 WELDING EQUIPMENT GROUNDING

The precautions and requirements listed below will apply when welding.

14.9.1 WELDING IN FABRICATION AREAS OR ERECTION FACILITY --

a. The grounding method will assure an absence of stray current in the circuit and an absence of arcing at the ground connection to the work.

b. The return cable to any welding generator will be grounded to the assembly or structure it is servicing.

c. All welding cable used in each welding circuit either in the electrode or in the ground (return) side of the circuit will be insulated, and the insulation will be maintained in a manner that conforms to approved standards.

d. Grounding cable lugs will be tightly secured to grounding plates. The lug contact area will be throughly cleaned to bare metal.

e. Cross-sectional area of the return ground cable will be 1 million circular mils minimum per 1,000 amperes of welding current per 100 feet of cable length. Two or more cables may be connected in parallel to meet the minimum cross-sectional area requirement.

14.9.2 SHIP WATERBORNE OR IN DOCK -- When welding is performed while the ship is waterborne or in dock, the requirements of Section XIII of NAVSEA 0901-LP-920-0003 (Chapter 9920 of Naval Ships Technical Manual) will apply.

e. Rivets with cracked heads or points.

f. Rivets with heads or points not in satisfactory contact with plate surfaces as specified above in paragraph 16.7.1.

g. Evidence of damage (buckling, cracking, etc.) of surrounding material.

16.7.2.2 Replacement of Defective Lockpins and Bolts -- Defective lockpins or bolts and nuts, will be removed and replaced whenever inspection and testing reveal any of the following types of defects:

a. Loose lockpins or bolts and nuts.

b. Lockpins, bolts and nuts which do not meet contact requirements specified above in paragraph 16.5.1.

c. Lockpins with cracked heads or collars or bolts with cracked heads or nuts.

16.8 EXTENT OF INSPECTION

16.8.1 FULL INSPECTION -- Each fastener employed in the following applications will be subjected to visual and tightness inspection:

a. All joints located in structure designated critical as defined in paragraph 6.4.2.1 of this document.

b. Fasteners in major machinery foundations.

16.8.2 LIMITED INSPECTION -- Fasteners used for structural applications other than those specified above in paragraph 16.8.1 will be subject to 100 percent visual inspection and 10 percent tightness and testing as specified above in paragraph 16.7.1. If defective fasteners are found on 10 percent inspection, the scope of inspection will be expanded until assurance of satisfactory quality is demonstrated to the inspector.

16 / MECHANICAL FASTENERS

16.1 SCOPE

This section contains the requirements for mechanical fastening and structural riveting when used on the 3KSES hull structure.

16.2 GENERAL

16.2.1 REQUIREMENTS -- The materials, design, and installation of structural riveting and other mechanical fastening specified on the drawings will meet the requirements of this section.

16.2.2 FASTENER APPLICATIONS -- Although welding is the preferred method of joining 3KSES structures, mechanical fasteners will be used where frequent and timely access is required and where characteristics of the structure, material, or environment prohibit the use of welding. Typical conditions where welding would be prohibited include attachments of resilient foundation mounts; attachments of steel components (e.g. fire door frames); and attachment of hardware, which requires removal for maintenance, to fuel tank boundaries.

16.2.3 CORROSION PROTECTION -- Corrosion effects will be considered in the design of mechanically fastened joints. Faying surfaces of aluminum to-aluminum joints and joints between dissimilar materials will be protected as specified below in paragraph 16.5.

16.2.4 FASTENER SELECTION -- Fasteners will be procured, installed, and inspected in accordance with approved specifications, procedures, and standards selected from the following in order of preference:

a. Government Specifications, Standards, and Procedures

b. Commercial Specifications, Standards, and Procedures

c. Vendor Specifications, Standards, and Procedures

d. Contractor Specifications, Standards, and Procedures

Standard types, sizes and lengths of fasteners will be used, whenever practicable, to facilitate maintenance replacement.

16.3 DESIGN REQUIREMENTS

16.3.1 GENERAL -- Designs for mechanically fastened joints will provide adequate strength for static, impact, and fatigue loadings, as appropriate, and will provide required joint tightness.

16.3.1.1 Critical Structure -- Fasteners in critical structure, as defined in Section 6 of this document, will be close tolerance or hole filling, will be positive locking or self-locking, and will have high reliability under the specified operational environment.

16.3.1.2 Other Structure -- Fasteners in other than critical structure will be positive locking or self-locking and will comply with standard tolerances. Mechanical fastening of assemblies, the failure of which would not result in failure to the ship or component, may be of any satisfactory type as specified on the drawings.

16.3.1.3 Composite Joints Both Welded and Mechanically Fastened -- The ship will be designed and constructed to avoid composite joints and thus permit the fasteners and welding employed therein to function independently of each other. Usage of composite joints, if required, will be limited to the types of joint designs (Reference Drawing TT802024A, -59, 61 and -63 assemblies) which have proven satisfactory in tests conducted per Structural Panel Test Plan TTP00016A.

16.3.2 APPLICATION OF RIVETS

The use of standard types of rivets will be in general accordance with the following:

16.3.2.1 Countersunk Rivets -- Countersunk heads or points (formed heads) will be used where flush surfaces are required or where calking of the head or point is necessary to insure proper oiltightness or watertightness of the joint.

16.3.2.2 Buttonhead Rivets -- Button heads or points will be used where projection of the head or point is not objectionable, where higher strengths are required, and where the necessary joint tightness can be achieved without resorting to calking of the head or the point.

16.3.2.3 Blind Rivets -- Blind rivets will not be used when the fastener is subjected to high tension loads or alternating shear stresses of significant magnitude or frequency.

16.3.3 APPLICATION OF OTHER MECHANICAL FASTENERS -- Bolt and nut fasteners and lockpins may be used for any joints except:

a. Where satisfactory tightness of the joint cannot be obtained.

b. Where the extension of the pin and collar, or bolt and nut would be unacceptable, or where clearances are inadequate for use of the proper installation tools.

16.3.4 SIZES OF MECHANICAL FASTENERS -- All fasteners will be of sufficient strength and length to assure structural adequacy for the function required. In connecting members of different thicknesses, the size of fasteners and the spacing will be at least adequate to develop the strength of the thinner or weaker member of the joint. If fatigue sensitivity is a consideration, then the outer row (or rows) of fasteners will have larger spacing than the row (or rows) closest to the joint.

16.3.5 ARRANGEMENT OF MECHANICAL FASTENERS

16.3.5.1 Joint Efficiencies -- The efficiency of a joint is the ratio of the load necessary to cause failure of the joint to the load necessary to cause failure of the unperforated weaker member. In joints of indefinite extent, efficiencies will be based on a unit strip through the joint of width equal to a repeating pattern of fasteners.

16.3.5.2 Fastener Spacing and Rows -- Fastener spacing and number of rows will be selected for maximum efficiency. In general, a zigzag pattern will be used where two or more rows of fasteners are required in attachments to plating or shapes, except an in-line pattern will be used in joints which are fatigue sensitive.

16.3.5.3 Edge Distance -- The distance from centers of fasteners to the edge of plates, shapes or straps in primary structure will be at least two times the fastener diameter. The edge distance may be reduced to not less than 1.5 times the fastener diameter when justified by stress analysis. Detail designs will assure provision of the specified minimum edge distance under the most adverse tolerance condition. When practicable, allowance will be made to permit the substitution of the next larger size fastener when required for repair or rework.

16.4 GENERAL FABRICATION REQUIREMENTS

16.4.1 TOOL MARKS -- Plating and shapes will not be marred nor show undue tool marks around fastener holes.

16.4.2 LINERS -- Liners (fillers or shims) will be fitted wherever necessary to secure proper connections of plates and shapes. Tapered liners will be of sufficient size to contain not less than two fasteners preferably including two rows.

16.4.3 HOLE FABRICATION -- All fastener holes will be drilled and deburred. Holes for close tolerance fasteners will be drilled and reamed to the diameter specified on the drawing. Punching of fastener holes will be prohibited.

16.4.4 UNFAIR HOLES -- No drifting to overcome unfair holes will be permitted. Where unfair holes occur, they will be drilled or reamed as appropriate, and fasteners suitable for the increased sizes of holes will be installed. New replacement structure with unfairness corrected will be provided whenever the number or the increased diameter of individual holes required to be enlarged for the purpose of removing unfairness will impair the strength of the structure below acceptable limits.

16.4.5 COUNTERSINKING -- Countersunk heads and points will not be more than 1/32 inch below the surfaces of the plate or shape fastening.

16.4.6 THREADED FASTENER INSTALLATION -- Threaded fasteners will be installed to the torque range specified on the drawing. Threaded parts will be dry or lubricated as specified on the drawing or process specification. A minimum of 1.5 threads to a maximum of 5 threads will protrude beyond the nut or locking device.

16.4.7 BURRS AND BUCKLES -- All burrs and chips will be removed, and all buckles and lumps will be faired out before any fastening is accomplished.

16.4.8 FASTENERS IN WAY OF WELDS -- Mechanical fastening of aluminum alloys, occurring within the area affected by the heat of welding (approximately 3 inches or less from the weld), will be done after welding is completed. All previously installed fasteners located within 6 inches of welding will be checked for tightness.

16.4.9 WELDING ACROSS MECHANICALLY FASTENED JOINT -- Butt welding across a mechanically fastened joint will be prohibited.

16.5 FAYING SURFACES

16.5.1 ALUMINUM TO ALUMINUM -- Faying surfaces of aluminum-to-aluminum will be coated with a minimum of one coat of zinc chromate primer, formula 84 of Fed. Spec. TT-P-645.

16.5.2 DISSIMILAR MATERIALS -- Where aluminum is to be joined to other metals including galvanized steel, each metal faying surface will be protected by two coats of primer forumla 84 of Fed. Spec. TT-P-645 over one coat of formula 117 of MIL-P-15328. If a vinyl system is to be used, two coats of formula 120 of MIL-P-15930 will be used in lieu of formula 84 of Fed. Spec. TT-P-645.

Where one or both sides of the aluminum to dissimilar metal joints are exposed to the weather, sea water, or wet spaces, a minimum thickness of 20 mils of insulation tape per Federal Specification HH-I-595 (three layers) or other NAVSEA approved equivalent will be installed between the faying surfaces to extend beyond the edge of the joint. For dissimilar metal joints in dry spaces, each faying surface will be coated with one coat of zinc chromate primer, formula 84 of Fed. Spec. TT-P-645, without installing insulation tape.

When dissimilar material fasteners are used, adequate corrosion protection will be provided. Steel fasteners in contact with aluminum alloy will be passivated 316L CRES or A-286. MP35N or MP159 fasteners may also be used when selection of these fasteners can be justified. All such fasteners will be installed in accordance with a written procedure approved by the Government Representative.

16.6 STOPWATERS AND OIL STOPS

16.6.1 GENERAL -- Stops (sealant for faying surfaces) will not be used to correct defective workmanship or materials, nor where the best practice requires metal-to-metal contact.

16.6.2 MATERIALS -- Stop material will be plastic insulation tape per Federal Specification HH-I-595 or other NAVSEA approved equivalent. Gunning mixture for oil stops will comply with formula 64 of MIL-C-18255 or approved equivalent.

16.6.3 INSTALLATION -- Materials of stopwaters must be fresh, and the work in way thereof must be fastened up before the material has hardened. Stops will not be inserted more than one week before fastening is started. The material of the stops must not prevent properly drawing the members close together for tight fastening and effective calking.

16.6.4 WELDING STOPWATERS AND OIL STOPS -- Welding may be used to form stopwaters and oil stops as approved for the applicable design.

16.7 INSPECTION AND TESTING OF FASTENERS

16.7.1 GENERAL -- Quality of workmanship on fasteners will be determined by visual inspection supplemented by approved tightness tests. Fastener head contact will be acceptable if a 0.005-inch feeler cannot be passed under the head at any place more than 50 percent of the difference between the fastener head and fastener shank radii.

16.7.2 REPLACEMENT OF DEFECTIVE FASTENERS

16.7.2.1 Rivet Defects -- Rivets will be removed and replaced whenever inspection and testing reveal any of the following types of defects:

a. Loose rivets.

b. Countersunk rivets with points or heads below plate surfaces more than 1/32 inch.

c. Rivets with incompletely formed or improper size heads or points.

d. Rivets with eccentric heads or points.